Diagnostic Ultrasound

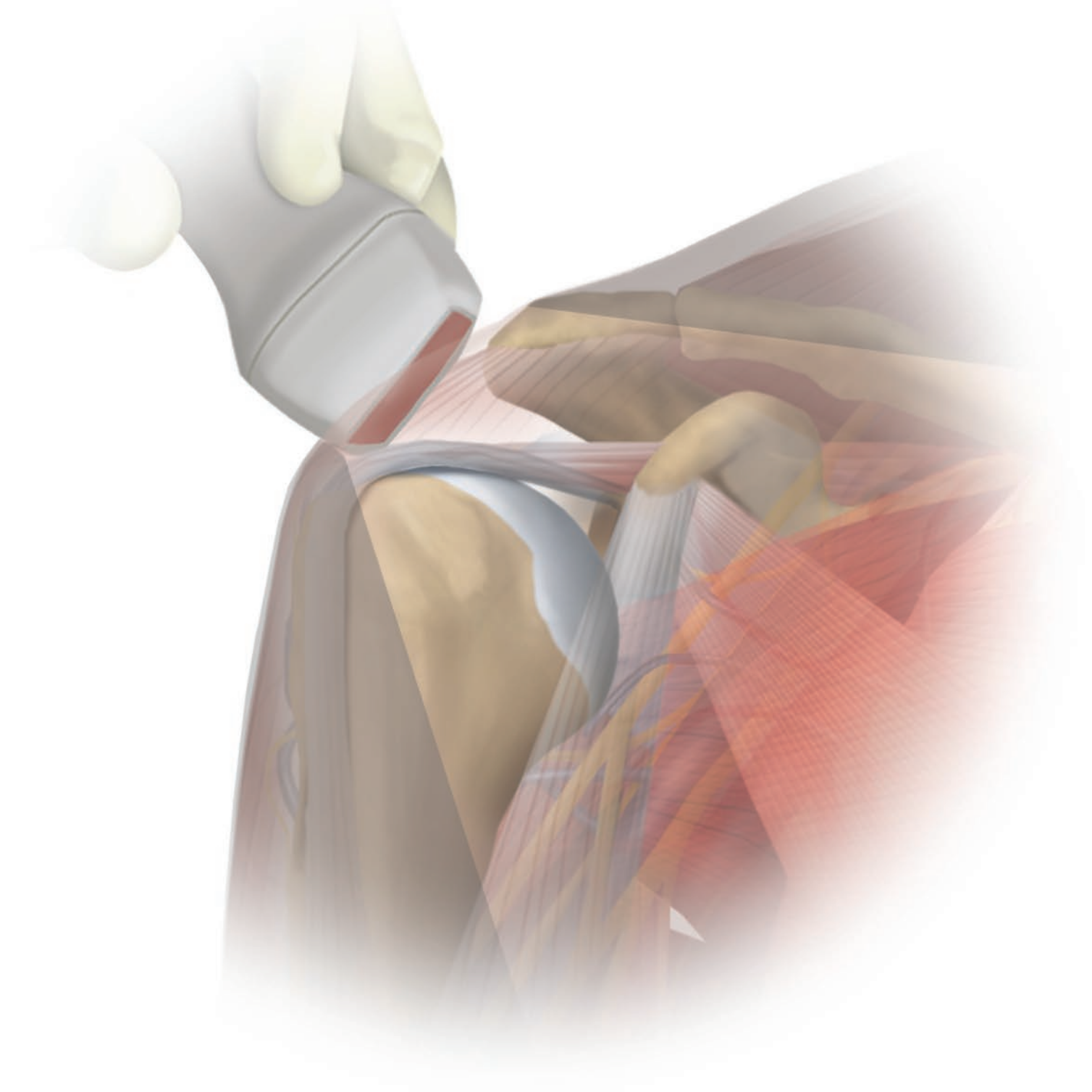
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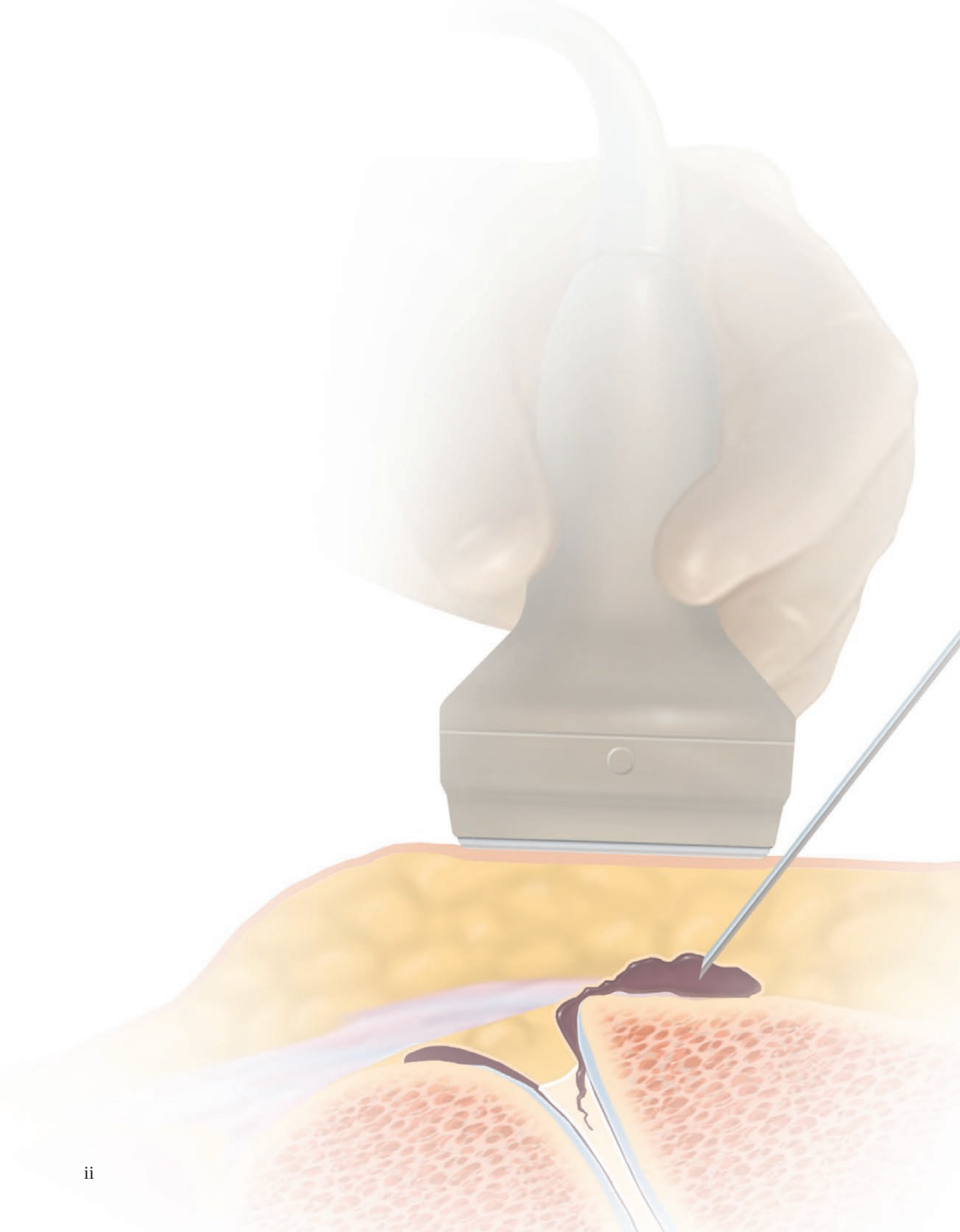
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Diagnostic Ultrasound

Musculoskeletal





Diagnostic Ultrasound
Musculoskeletal



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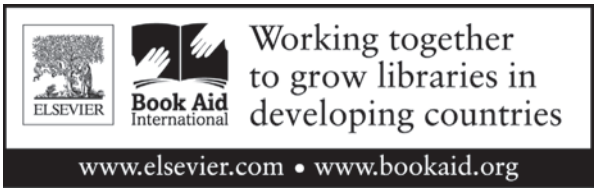
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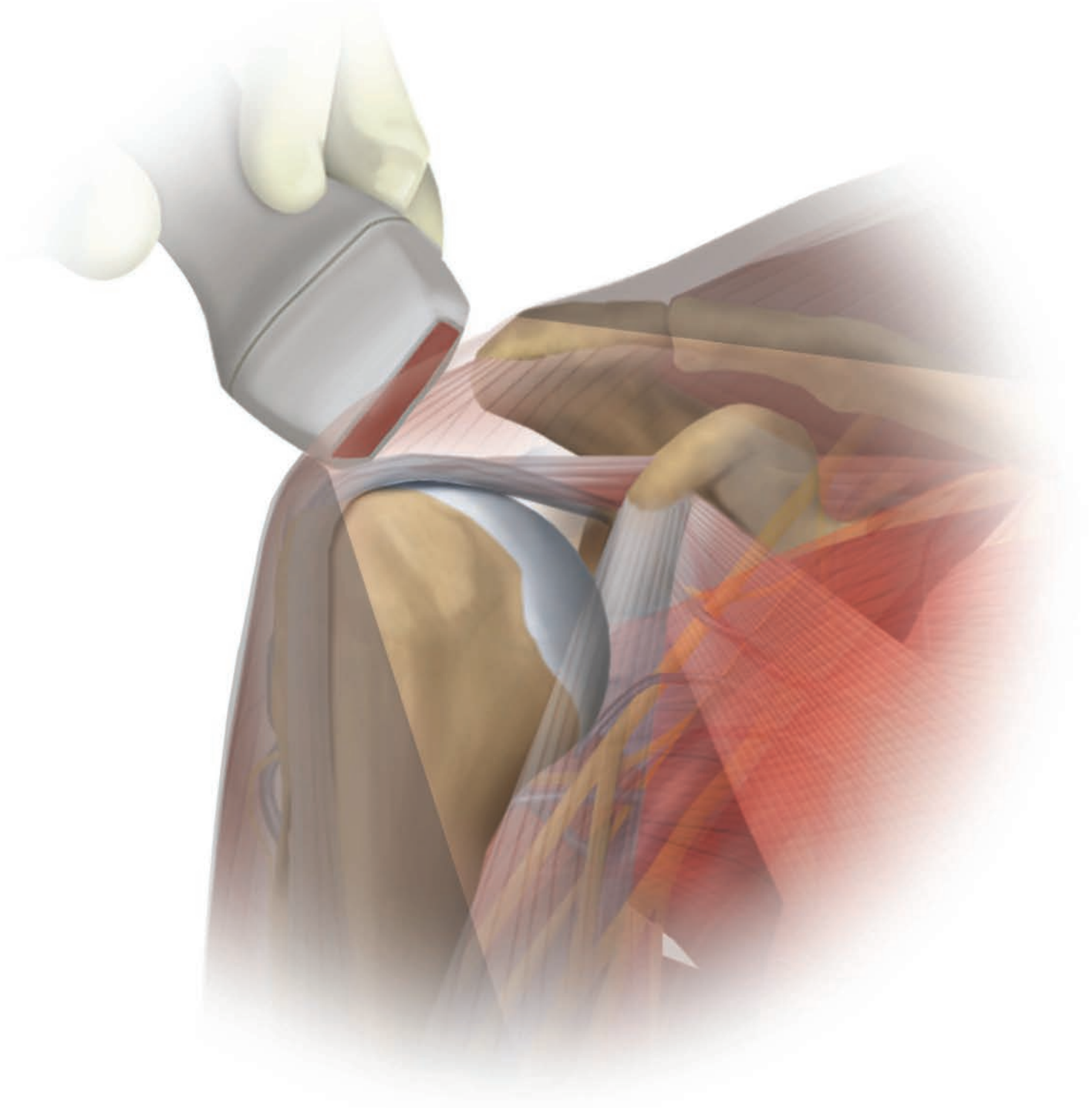
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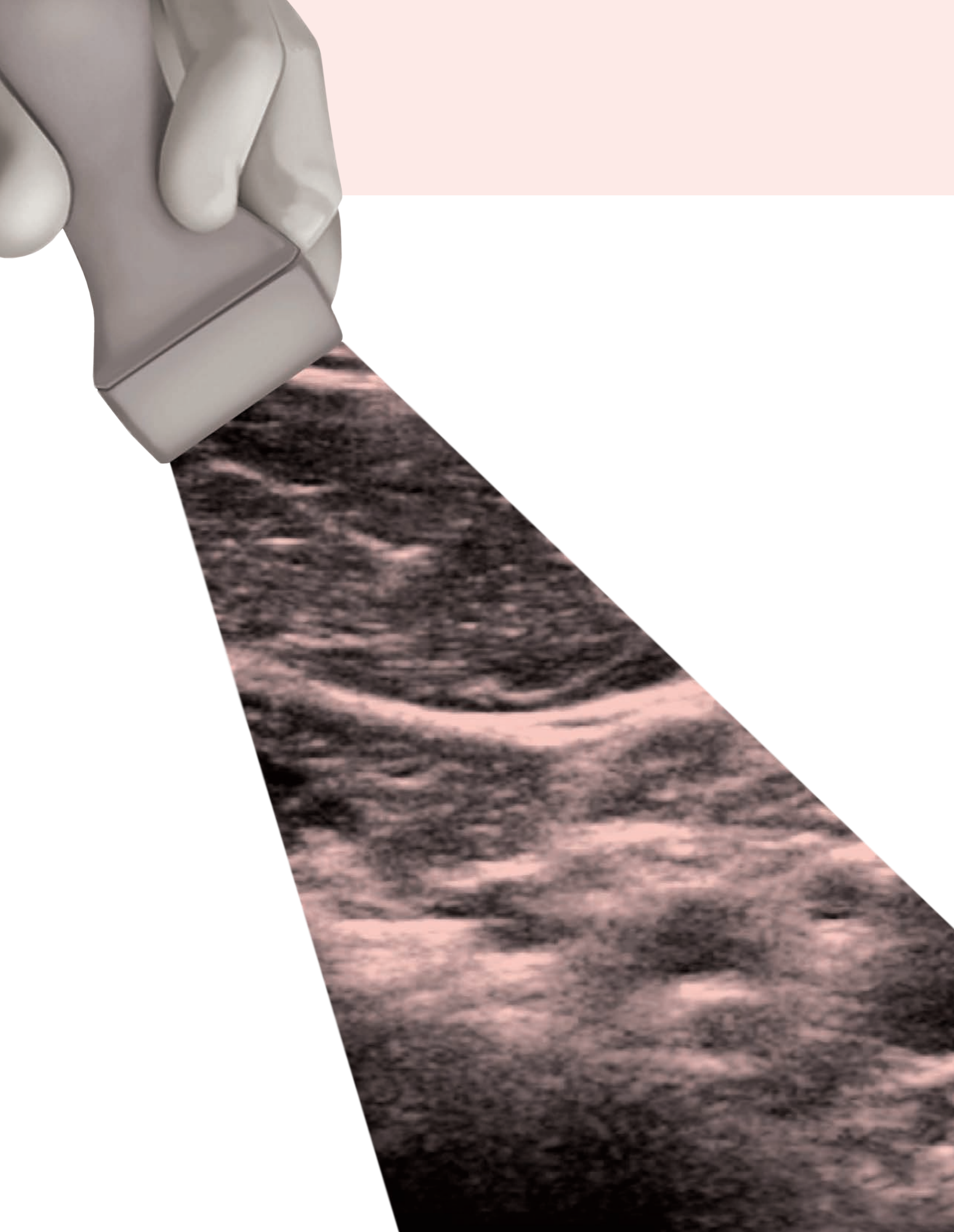
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Diagnostic Ultrasound

Musculoskeletal

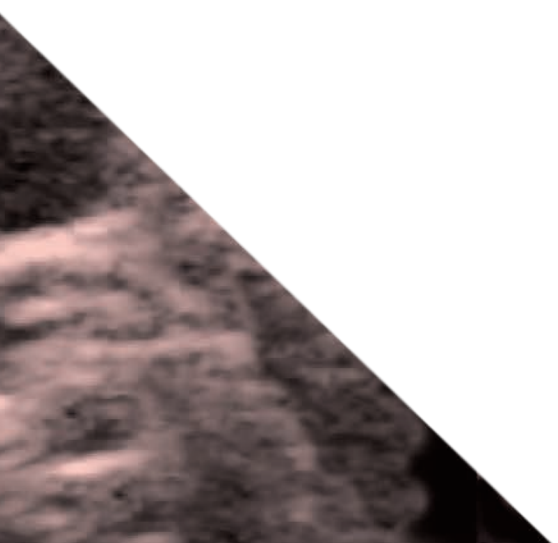




SECTION 1

Upper Limb

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STERNOCLAVICULAR AND ACROMIOCLAVICULAR JOINTS

TERMINOLOGY

Abbreviations

- Sternoclavicular (SC) joint
- Acromioclavicular (AC) joint

GROSS ANATOMY

Sternoclavicular Joint

- Between medial end of clavicle and manubrium
  - Synovial sellar-type (saddle) joint
  - Medial end of clavicle = large and bulbous
  - Much larger than manubrial concavity
  - < 1/2 of medial clavicle articulates with manubrium
    - Stability through capsuloligamentous structures
- Intraarticular disc
  - Attached to joint capsule anteriorly and posteriorly
  - Complete or incomplete ± perforations
  - Thickest posterosuperiorly (3 mm)
- Ligaments of sternoclavicular joint
  - Capsular ligaments
    - Cover anterosuperior and posterior aspects of sternoclavicular joint
    - Prevent upward displacement of medial clavicle, which may be caused by downward force on shoulder
    - Anterior stronger than posterior portion
  - Interclavicular ligament
    - Connects superomedial aspect of clavicle to capsular ligaments and upper manubrium
    - Covers anterosuperior and posterior aspects of joint
    - Prevents excessive upward motion of clavicle
  - Costoclavicular ligaments
    - Unite inferior surface medial end clavicle to upper surface of 1st rib
    - Anterior fibers arise from anteromedial surface of 1st rib and resist upward motion
    - Posterior fibers arise lateral to anterior fibers and resist downward motion
- Muscle attachments to medial clavicle and sternum
  - Pectoralis major from anterior aspect medial 2/3 clavicle (clavicular head)
  - Sternocleidomastoid from posterior surface medial 1/3 of clavicle (clavicular head)
  - Sternohyoid and sternothyroid muscles separate great vessels from sternoclavicular joint

Acromioclavicular Joint

- Synovial joint between lateral end of clavicle and medial end of acromion
  - Articular surface of clavicle oriented posterolaterally whereas articular surface of acromion oriented anteromedially
    - Angle of inclination between opposing articular surfaces varies with clavicle overriding acromion (50%), vertical orientation between acromion and clavicle (25%), clavicle underriding acromion (5%), and mixed pattern (20%)
    - Maximum width of normal joint on ultrasound = 5 mm if < 35 years and < 4.4 mm if > 35 years
    - Maximum thickness of capsule from bony surface = 2.7 mm if < 35 years and < 3.6 mm if > 35 years
- Intraarticular disc
  - Undergoes rapid degeneration beginning in 2nd decade → marked degeneration of disc by 4th decade
- Ligaments of AC joint
  - Superior AC ligament
    - Stronger and thicker (2.0-5.5 mm) than thin or absent inferior AC ligament
    - Inserts along lateral clavicle (8 mm) and medial acromion (10 mm)
  - Coracoclavicular ligaments
    - Conoid and trapezoid ligaments
    - Vary significantly in length and width
    - Conoid ligament located posteromedially
    - Inserts to conoid tubercle which is located where middle 1/3 of clavicle curves into lateral 1/3 of clavicle
    - Mainly prevents upward movement of clavicle
    - Trapezoid ligament located anterolaterally
    - Inserts to trapezoid ridge, which runs along inferior surface, of lateral 1/3 of clavicle
    - Mainly prevents lateral compression of clavicle against acromion
  - Muscle attachments to lateral clavicle
    - Deltoid attached to anterior surface lateral 1/3 of clavicle
    - Trapezius attached to posterior surface lateral 1/3 of clavicle

ANATOMY IMAGING ISSUES

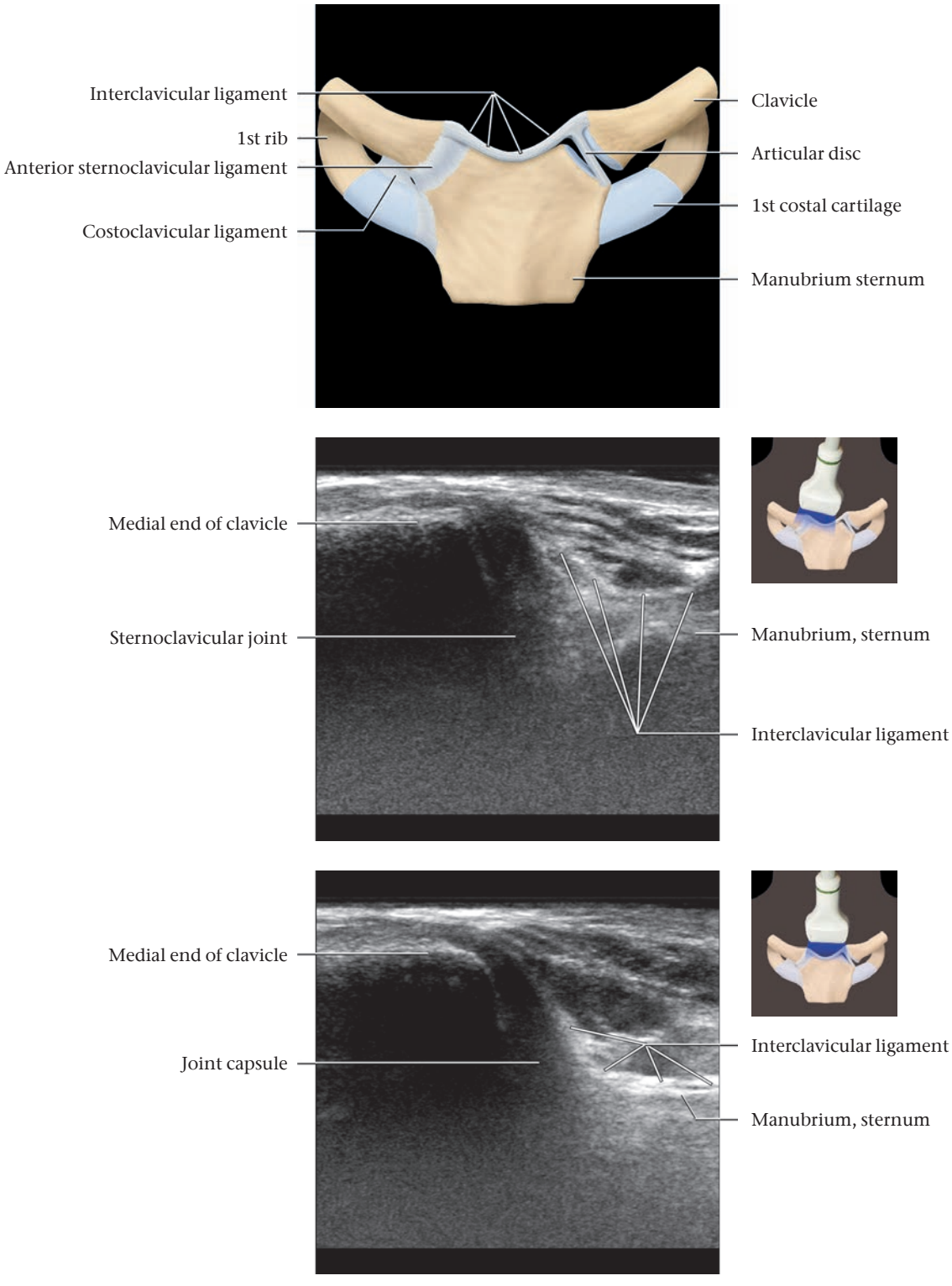
Imaging Recommendations

- High-resolution linear transducer
- Align transducer transversely along SC or AC joints
- AC joint laxity can be assessed by pulling down on arm while observing change in joint width on ultrasound
  - Compare with contralateral side
- Main clinical presentation of SC joint is painless lump
  - Mild degrees of capsular thickening readily apparent clinically since joint just beneath skin surface
    - Clinical swelling often due to relative forward positioning of apparently swollen SC joint due to axial rotation of upper trunk
    - Occasionally due to mild capsular swelling ± mild subluxation secondary to SC osteoarthritis
  - Main clinical presentation of AC joint is pain due to osteoarthritis, AC joint impingement, inflammatory arthropathy, and subluxation/dislocation

Imaging Pitfalls

- SC or AC joints
  - Normally a step-off between medial clavicle and manubrium and, to lesser degree, between lateral clavicle and acromion
  - Should not be interpreted as subluxation
  - Acromion normally elevates from rest position during arm adduction
  - AC joint index = AC joint width of uninjured side/AC joint width of injured side = 1.0 normally
  - Determine whether
    - AC joint not subluxed (similar to opposite side) : Grade 1
    - AC joint partially subluxed (clavicle subluxed < 50% depth of AC joint) : Grade 2
    - AC joint severely subluxed or dislocated (clavicle subluxed > 50% depth of AC joint) : Grade 3

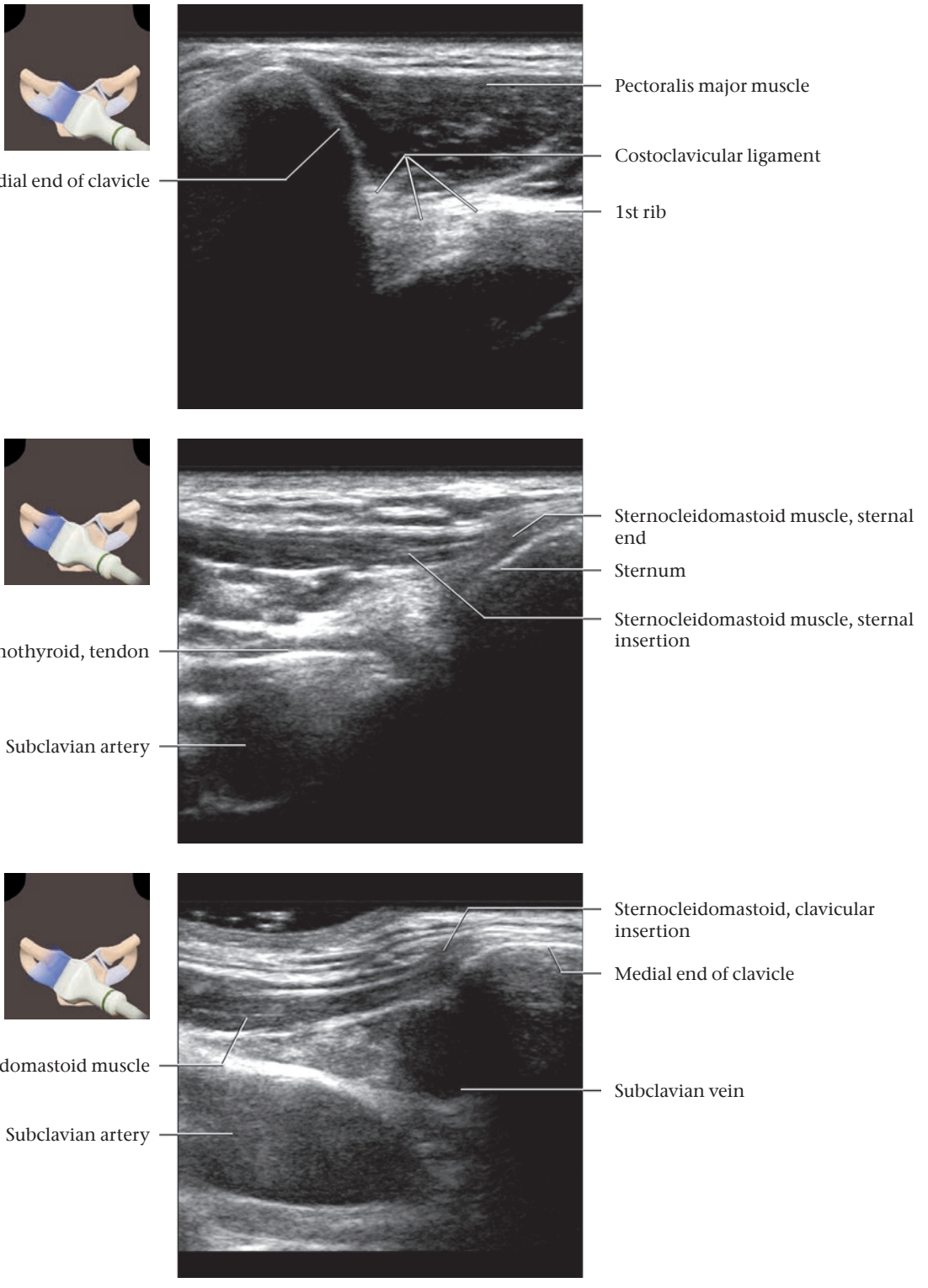
TRANSVERSE US, STERNOCLAVICULAR JOINT



(Top) *Graphic shows the anterior aspect of the sternoclavicular joint. Note the joint capsule, articular disc, and interclavicular ligament.* ***(Middle)*** *Transverse grayscale ultrasound shows the anterosuperior aspect of the sternoclavicular joint. The medial clavicle is much larger than the articulating surface of the manubrium. The thin interclavicular ligament is closely applied to the superior aspect of manubrium, and its connection with the medial ends of both clavicles is depicted.* ***(Bottom)*** *Transverse grayscale ultrasound shows the superior aspect of the sternoclavicular joint. The costoclavicular ligament prevents upward movement of the medial clavicle when the lateral clavicle or shoulder is depressed.*

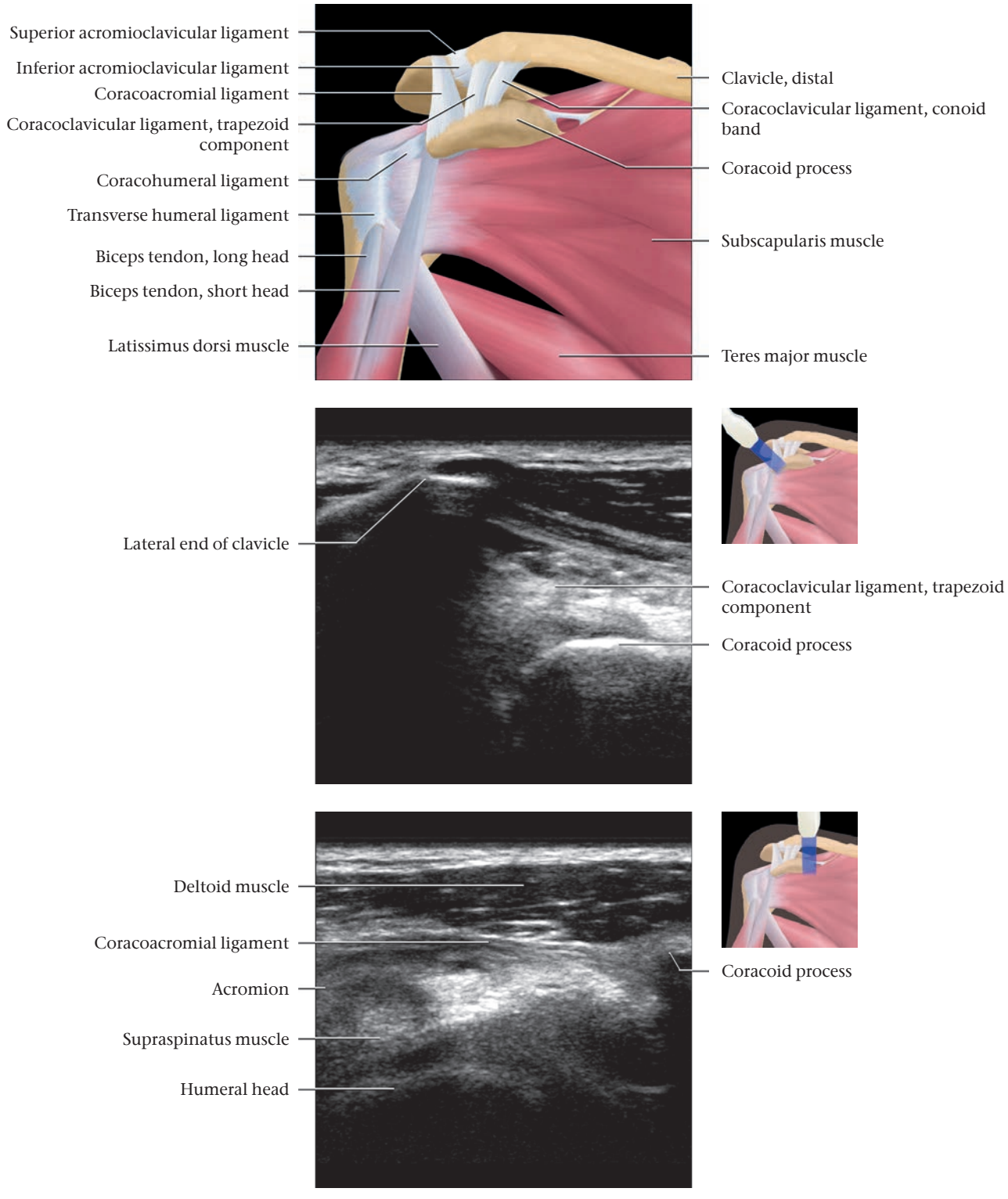
STERNOCLAVICULAR AND ACROMIOCLAVICULAR JOINTS

LONGITUDINAL US, STERNOCLAVICULAR JOINT



(Top) *Longitudinal grayscale US shows sternoclavicular joint. Costoclavicular ligament prevents upward movement of the medial clavicle when shoulder is depressed. Pectoralis major muscle arises from the medial 1/2 of the anterior surface of the clavicle as well as from the sternum, upper costal cartilages, and upper part of external oblique aponeurosis.* ***(Middle)*** *Longitudinal grayscale US shows sternoclavicular joint region. Sternocleidomastoid is attached to the upper surface of the medial end of the clavicle as well as the upper anterior surface of the manubrium. Sternohyoid and sternothyroid are attached to the posterior aspect of the sternum as well as the clavicle and 1st costal cartilage.* ***(Bottom)*** *Longitudinal grayscale US shows sternoclavicular joint. Great vessels lie posterior to sternoclavicular joint and may get injured in posterior dislocation. All tendinous attachments should be assessed if dislocation is present as they may also be injured.*

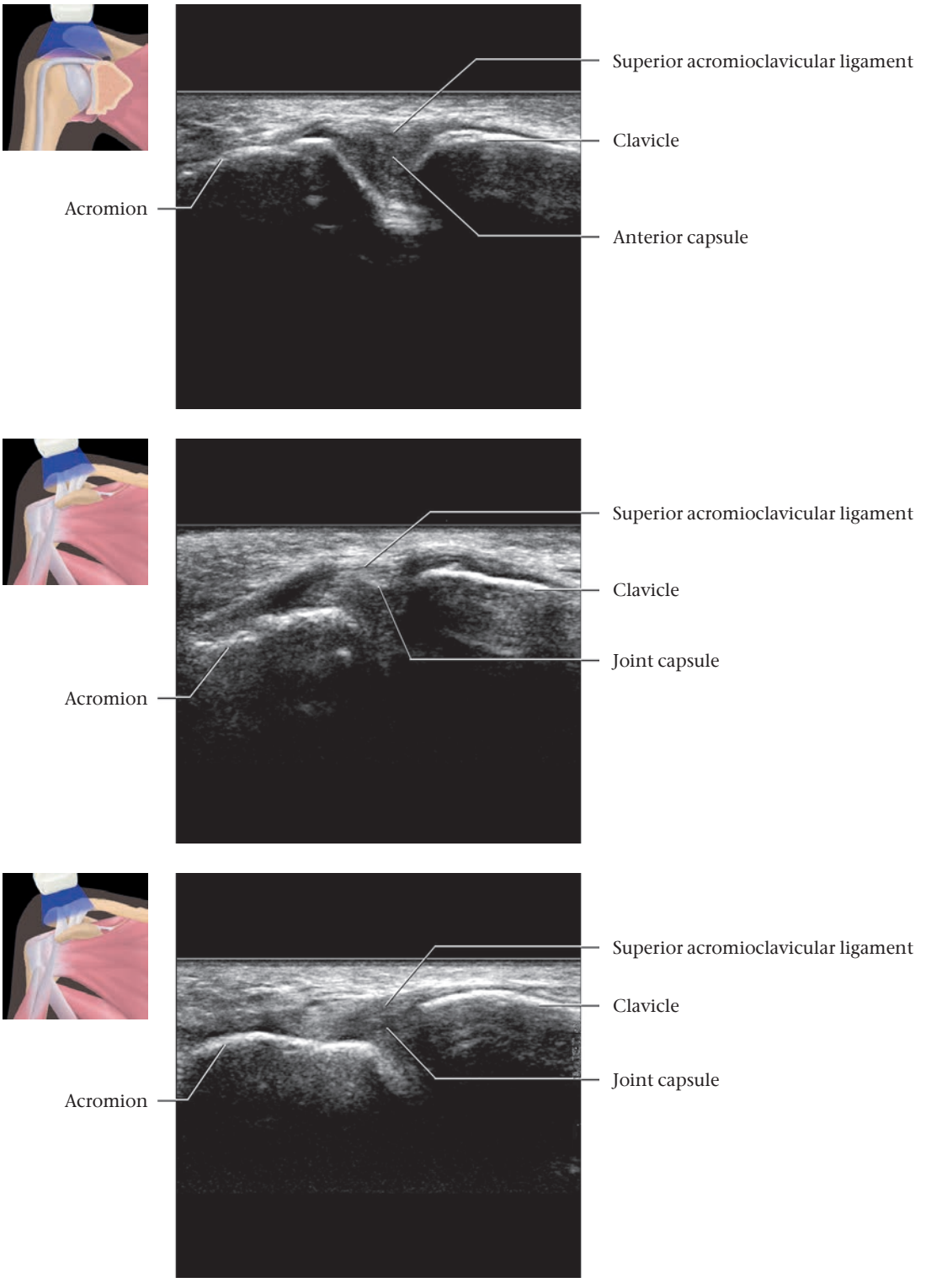
US, ACROMIOCLAVICULAR JOINT



(Top) *Anterior graphic shows the shoulder in superficial dissection.* ***(Middle)*** *Longitudinal grayscale ultrasound shows the acromioclavicular joint region. The coracoclavicular ligament is demonstrated but is not as clearly depicted on US as it is on MR exam. These ligaments prevent upward and lateral movement of the clavicle.* ***(Bottom)*** *Transverse grayscale ultrasound of the acromioclavicular joint region shows the coracoacromial ligament. The supraspinatus tendon and intervening bursa can impinge against the coracoacromial ligament during arm abduction.*

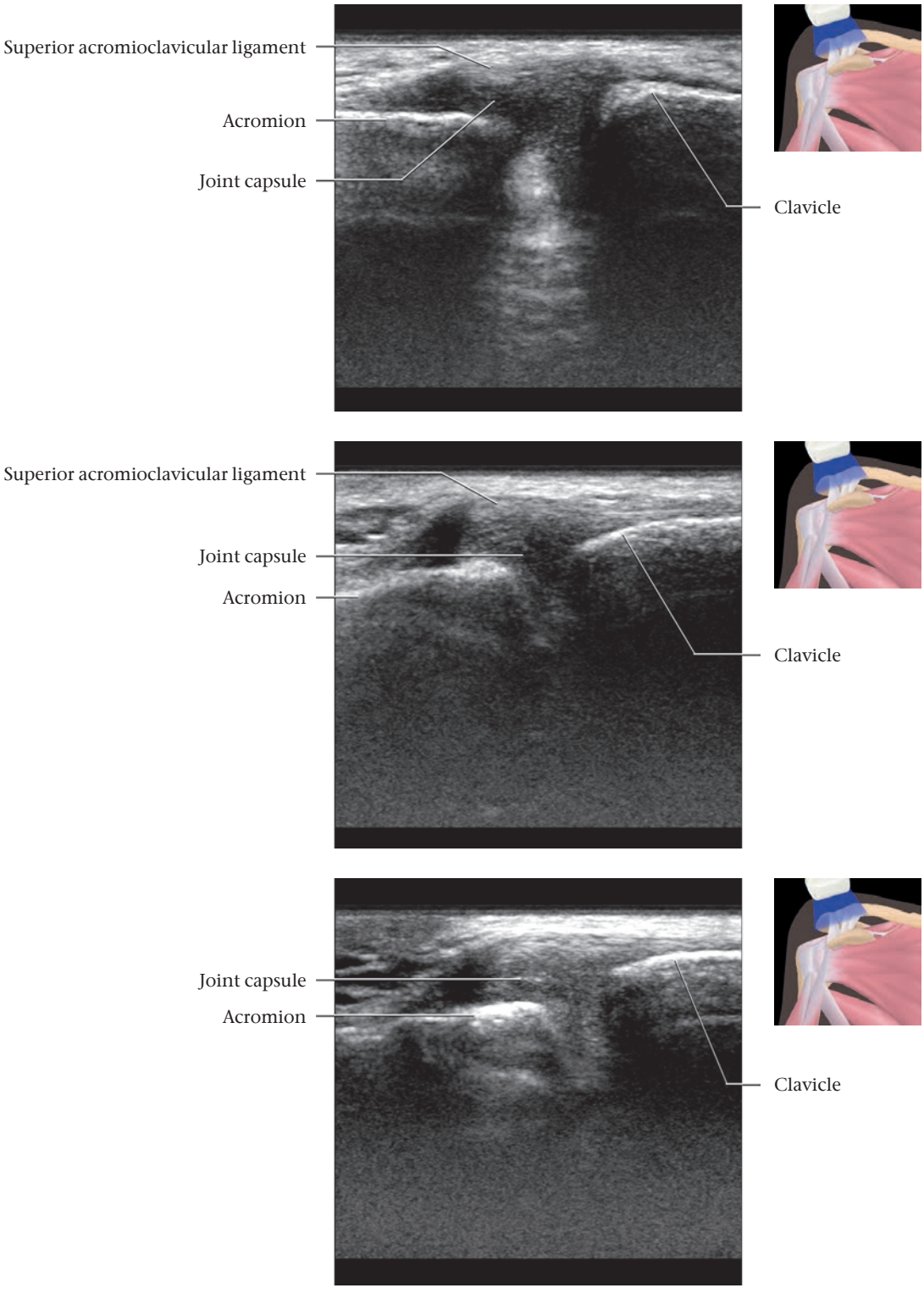
STERNOCLAVICULAR AND ACROMIOCLAVICULAR JOINTS

TRANSVERSE US, ACROMIOCLAVICULAR JOINT



(Top) *Transverse grayscale ultrasound shows the anterior aspect of the acromioclavicular joint. The joint capsule of the acromioclavicular joint is thin with a strong supporting superior acromioclavicular ligament.* ***(Middle)*** *Transverse grayscale ultrasound shows the anterosuperior acromioclavicular joint. Separation of the clavicle and acromion can be readily appreciated. Note how opposing bone margins are not vertically aligned.* ***(Bottom)*** *Transverse grayscale ultrasound shows the superior aspect of the acromioclavicular joint. In this image, the clavicle slightly overrides the acromion. This is a normal configuration.*

TRANSVERSE US, ACROMIOCLAVICULAR JOINT



(Top) *Transverse grayscale ultrasound shows the anterosuperior aspect of the acromioclavicular joint with the arm positioned by the side of the body. Note that the clavicle slightly overrides the acromion.* ***(Middle)*** *Transverse grayscale ultrasound shows the acromioclavicular joint with the arm in abducted position. The acromion is now level with the lateral aspect of the clavicle. Note how the joint capsule bulges superiorly and the opposing bones are approximated with the arm abducted.* ***(Bottom)*** *Transverse grayscale ultrasound shows the acromioclavicular joint with the arm in an adducted position. The acromion is now depressed relative to this lateral end of the clavicle.*

SHOULDER

IMAGING ANATOMY

Overview

- **Rotator cuff**
  - Consists of supraspinatus, infraspinatus, teres minor, subscapularis muscles, and tendons
  - Cuff tendons blend with shoulder joint capsule
  - Supraspinatus and infraspinatus tendons are inseparable at insertion
  - Anterior 2.25 cm of tendon comprises supraspinatus tendon insertional area
- **Supraspinatus muscle**
  - Origin: Supraspinatus fossa of scapula
  - Insertion: Superior facet (horizontal orientation) and anterior portion of middle facet of greater tuberosity
    - Broad insertional area
  - Nerve supply: Suprascapular nerve
  - Blood supply: Suprascapular artery and circumflex scapular branches of subscapular artery
  - Action: Abduction of humerus
  - Muscle consists of 2 distinct portions
    - Anterior portion is larger, fusiform in shape, has dominant tendon, and is more likely to tear
    - Posterior portion is flat and has terminal tendon
  - Most commonly injured rotator cuff tendon
- **Infraspinatus muscle**
  - Origin: Infraspinatus fossa of scapula
  - Insertion: Mid to posterior aspects of middle facet of greater tuberosity
    - Centrally positioned within tendon
  - Nerve supply: Suprascapular nerve, distal fibers
  - Blood supply: Suprascapular artery and circumflex scapular branches of subscapular artery
  - Action: External rotation of humerus and resists posterior subluxation
- **Teres minor muscle**
  - Origin: Lateral scapular border, middle 1/2
  - Insertion: Inferior facet (vertical orientation) of greater tuberosity
  - Nerve supply: Axillary nerve
  - Blood supply: Posterior circumflex humeral artery & circumflex scapular branches of subscapular artery
  - Action: External rotation of humerus
  - Least commonly injured rotator cuff tendon
- **Subscapularis muscle**
  - Origin: Subscapular fossa of scapula
  - Insertion: Lesser tuberosity and up to 40% may insert at surgical neck
  - Also some fibers cross over to lateral lip of bicipital groove reinforcing and blending with fibers of transverse ligament
  - Nerve supply: Subscapular nerve, upper and lower
  - Blood supply: Subscapularis artery
  - Action: Internal rotation of humerus, also adduction, extension, depression, and flexion
  - 4-6 tendon slips converge into main tendon; multipennate morphology increases strength
- **Rotator cuff tendon blood supply**
  - Derived from adjacent muscle, bone, and bursae
  - Normal hypovascular regions in tendons
    - Termed "critical zone" ~ 1 cm proximal to insertion
    - This area is vulnerable to degeneration and calcific deposition
    - However, insertional area is more prone to tearing than critical zone
- **Biceps tendon, long head**
  - Origin: Superior glenoid labrum (biceps anchor)
    - Portions may attach to supraglenoid tubercle, anterosuperior labrum, posterosuperior labrum, and coracoid base
  - Runs along superior aspect shoulder to bicipital groove
  - Action: Stabilizes and depresses humeral head
  - Anatomic variants: Anomalous intra- & extraarticular origins from rotator cuff and joint capsule
  - Tendon sheath communicates with glenohumeral joint and normally contains small amount of fluid
- **Subacromial-subdeltoid fat plane**
  - Subacromial and subdeltoid portions
    - ± subcoracoid extension in some patients
  - Fat plane is superficial to bursa
  - May be interrupted or absent in normal patients
  - Attached along free border of coracoacromial ligament and adjacent deep surface of deltoid muscle, and humeral neck region
- **Rotator cuff interval**
  - Space between supraspinatus and subscapularis tendon through which biceps tendon passes
  - **Borders of rotator cuff interval**
    - Triangular-shaped space
    - Reflections of glenohumeral ligament and coracohumeral ligament form biceps reflection pulley
    - Biceps reflection pulley stabilizes biceps tendon within rotator cuff interval
    - Superior border: Leading edge of supraspinatus
    - Inferior border: Superior aspect subscapularis tendon
    - Lateral border: Long head of biceps tendon and bicipital groove
    - Medial border: Base of coracoid process
  - **Contents of rotator interval**
    - Long head of biceps tendon
    - Biceps reflection pulley
- **Coracoacromial ligament**
  - Forms coracoacromial arch along with acromion and coracoid process
    - Reinforces inferior aspect of acromioclavicular joint
  - Extends from distal coracoid to subacromial area
  - Broad insertion to undersurface acromion
    - Ligament is thicker at acromion (normal thickness < 2.5 mm) and may be associated with spurs
- **Glenoid labrum**
  - Triangular-shaped rim of fibrocartilage, which extends around periphery of glenoid

ANATOMY IMAGING ISSUES

Imaging Approaches

- Tendons best seen when on stretch
  - High-resolution linear transducer
  - Long-axis (longitudinal) and transverse view of each tendon
  - Each part of tendon needs to be examined; anisotropy prevents all parts of curved rotator cuff tendons being seen at same time
  - Need to realign ("toggle") probe to see different parts of tendons

- Supraspinatus tendon
  - Arm extended and internally rotated behind lumbar region (Crass position)
    - Or, if too painful, hand in posterior hip region ("back pocket") with elbow close to body (modified Crass position)
- Infraspinatus and teres minor tendons
  - Arm flexed and internally rotated with hand placed on contralateral shoulder
  - Teres minor tendon located posteroinferior to infraspinatus tendon
- Subscapularis tendon
  - Arm neutral and externally rotated
- Long head of biceps tendon
  - Arm neutral and externally rotated
  - Vary degree of external rotation for optimal view of biceps tendon
  - Check for tendon subluxation
- Subacromial-subdeltoid bursa
  - Stretching tendons may squeeze fluid from area of bursa under inspection
  - Examine in all positions and also in neutral position
  - Fluid collects preferentially just lateral to acromion, lateral to proximal humerus, and near coracoacromial ligament
- Coracoid process and coracoacromial ligament
  - Neutral position
- Acromioclavicular joint
  - Neutral position
  - Can pull down on arm when examining acromioclavicular joint to assess joint laxity
- Glenohumeral joint
  - Neutral position
  - Best seen from posterior aspect of joint
  - Passive movement of arm during scanning can help in identifying posterior glenoid labrum
- Spinoglenoid notch
  - Neutral position just medial to glenohumeral joint
- Supraspinatus and infraspinatus muscles
  - Neutral position with hands resting on thigh
  - Examine thickest part of muscles from behind (in coronal and sagittal planes)
  - ↓ muscle bulk, ↑ muscle echogenicity and reduced visibility of central tendon are signs of muscle atrophy with fatty replacement
    - Compare muscle echogenicity to that of trapezius or deltoid muscle

Imaging Sweet Spots

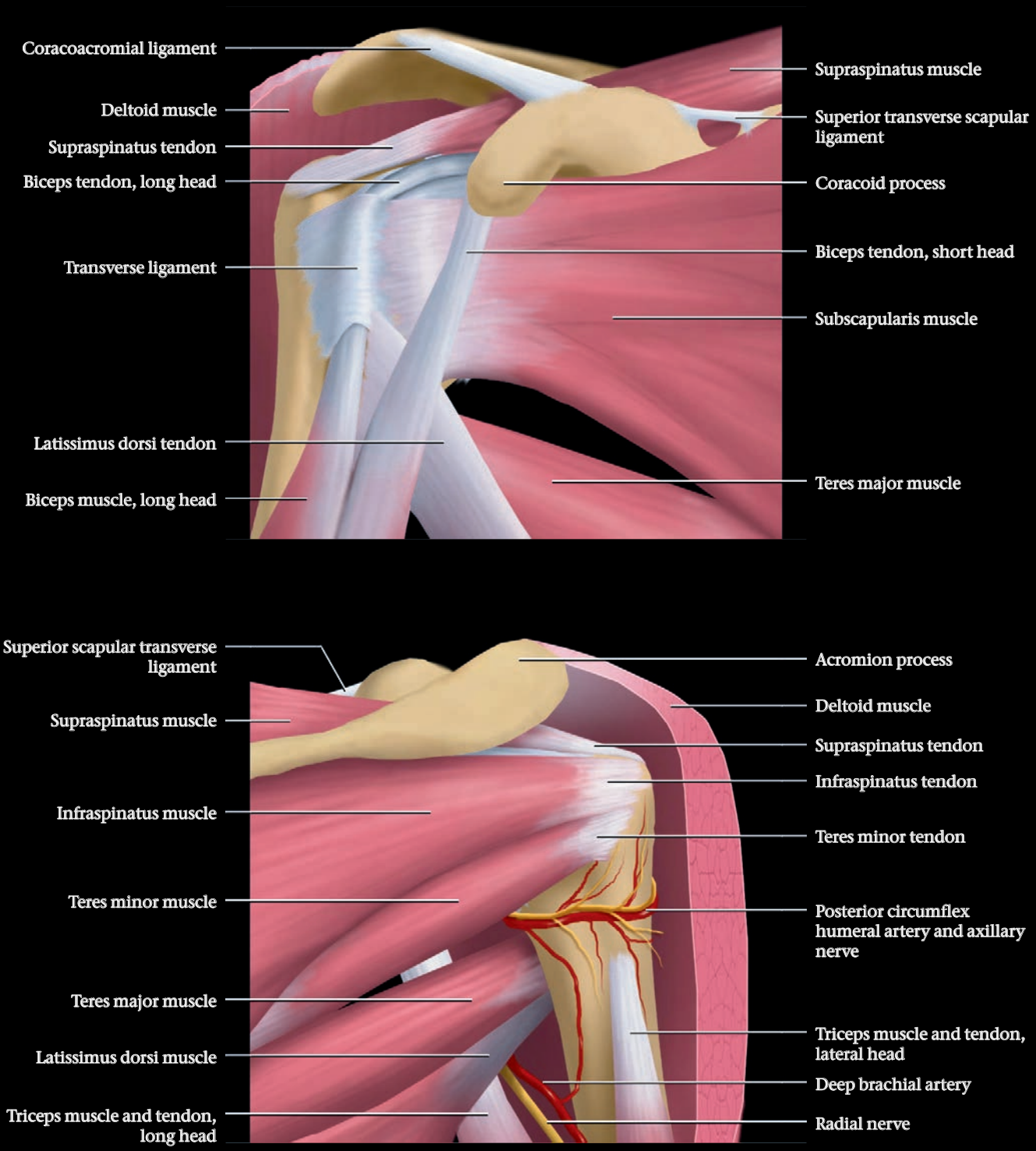
- Look for tears particularly at anterior leading edge of supraspinatus tendon
  - Unexplained bursal fluid is a good secondary sign of rotator cuff tear
- Bursal fluid is often best seen with arm in neutral position or ↓ internal rotation (hand in back pocket)

Imaging Pitfalls

- **Anisotropy**
  - Echoes are optimally reflected when transducer is parallel to tendon fibers
  - Rotator cuff tendons are prone to anisotropy due to curved course
  - If transducer is not at right angles to tendon, it will appear either isoechoic or hypoechoic to muscle
    - May simulate tendinosis or partial tear
- **Tendon edges**
  - Interfaces of tendons with adjacent structures may simulate tears
  - All tears and other tendon pathology should be confirmed in 2 planes
- **Rotator cuff cable**
  - Thick band of fibers running perpendicular to supraspinatus tendon
  - Located on deeper aspect of tendon just proximal to insertional area
  - May reinforce 'critical zone' supraspinatus fibers
  - Cable thicker in young subjects but more easily seen in elderly subjects due to supraspinatus tendinosis
  - Can simulate tendinosis or partial thickness tear
- **Tendinous interspace at rotator cuff interval**
  - Interspace between leading edge (anterior edge) of supraspinatus and long head of biceps tendon may simulate tear
  - Overcome by recognizing ovoid or rounded shape of biceps tendon
  - Rotator cuff interval best seen with arm in external rotation
- **Focal thinning at supraspinatus-infraspinatus junction**
  - Mild diffuse thinning of supraspinatus and infraspinatus tendon junction is normal finding
  - Should not be mistaken for tendon attenuation or partial thickness tear
- **Musculotendinous junction**
  - Supraspinatus tendon
    - Hypoechoic muscle extending along superficial aspect of tendon may simulate subacromial-subdeltoid bursal distension
    - Interdigitating tendons of anterior and posterior portions may simulate tendinosis or tear
  - Infraspinatus tendon
    - Muscle fibers surrounding centrally positioned tendon may be confused with tear
  - Subscapularis tendon
    - 4-6 tendon slips converging into main tendon may simulate tendinosis
- **Fibrocartilaginous insertion**
  - Thin layer of fibrocartilage exists between tendon and bone at insertional area
  - The steeper the tendon insertion, the thicker the fibrocartilaginous layer
  - This thin hypoechoic layer of fibrocartilage may simulate avulsive tear
- **Subacromial-subdeltoid fat plane**
  - Fat plane lies mainly superficial to bursa and deep to deltoid muscle
  - Normal bursa is very thin
  - Thickness of echogenic fat plane is variable among patients though usually similar from side to side
  - May be wrongly interpreted as bursal fluid
    - Look for intrabursal fluid ± hyperemia (latter is a feature of inflammatory arthropathy)
- **Fluid in biceps tendon sheath**
  - Communicates with glenohumeral joint
  - Small amount of fluid is normal
    - Do not misinterpret as long head of biceps tenosynovitis
  - ↑ fluid in biceps tendon sheath usually reflects ↑ fluid in glenohumeral joint

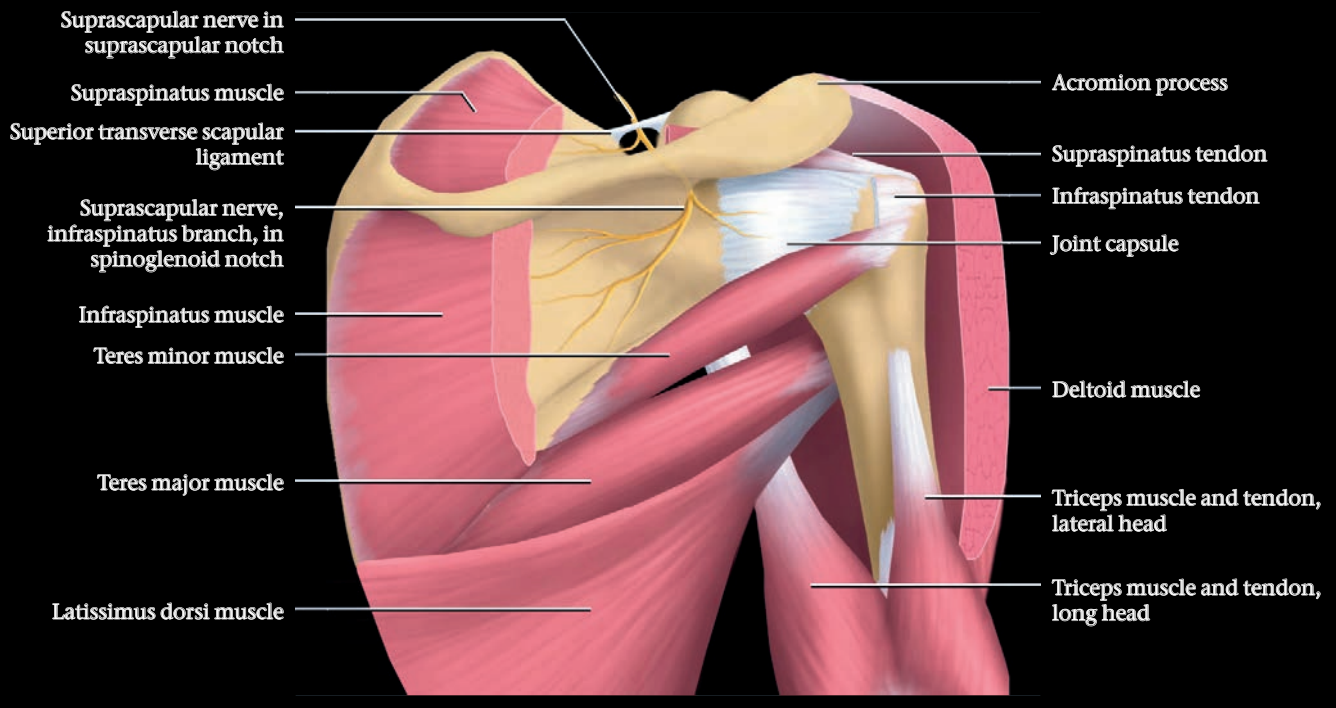
SHOULDER

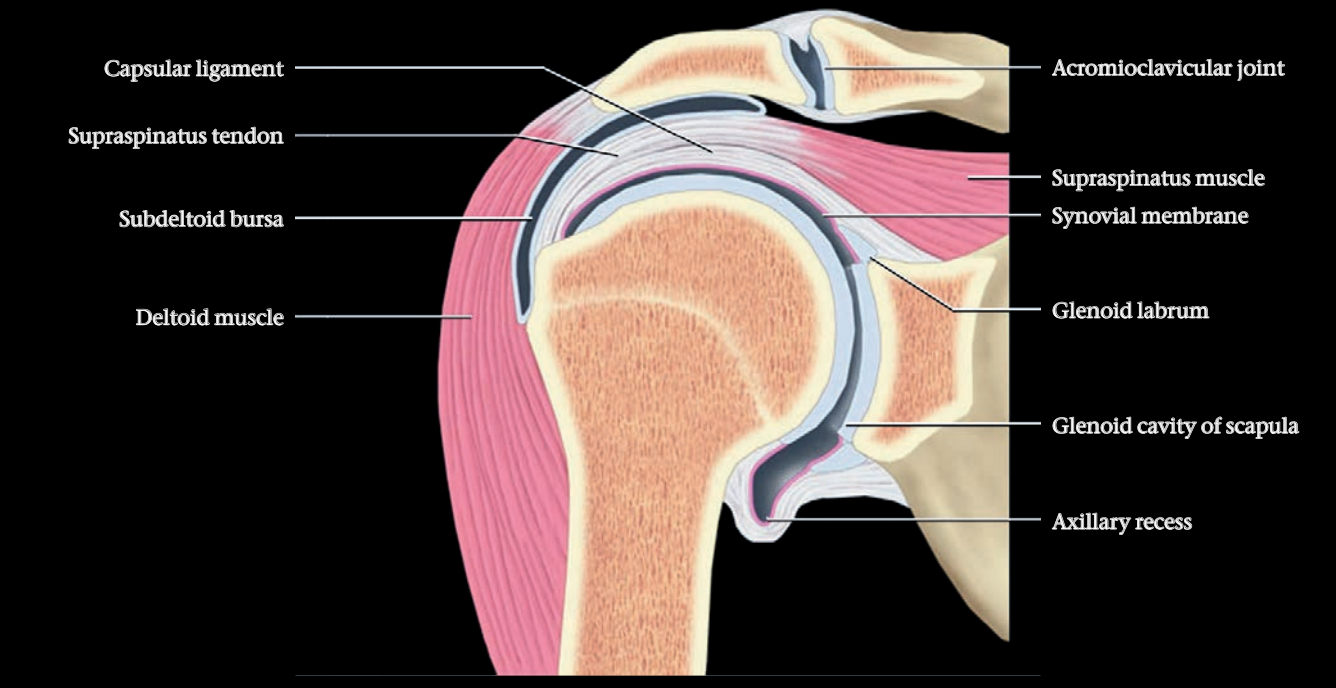
GRAPHICS, MUSCLES AND LIGAMENTS



(Top) *Anterior graphic of the shoulder illustrates the rotator cuff and adjacent structures. The rotator cuff consists of supraspinatus, infraspinatus, teres minor, and subscapularis muscles and tendons. The biceps tendon courses the rotator cuff interval between the supraspinatus and subscapularis tendons, then descends along the bicipital groove, which is covered by the transverse ligament.* ***(Bottom)*** *Posterior graphic of the shoulder illustrates the rotator cuff and adjacent structures. The infraspinatus and teres muscles and tendons form the posterior wall of the rotator cuff. Inferior to the teres minor muscle and superior to the teres major, is the axillary nerve and posterior circumflex humeral vessels running through a space named the quadrilateral space.*

GRAPHICS, DEEP STRUCTURES

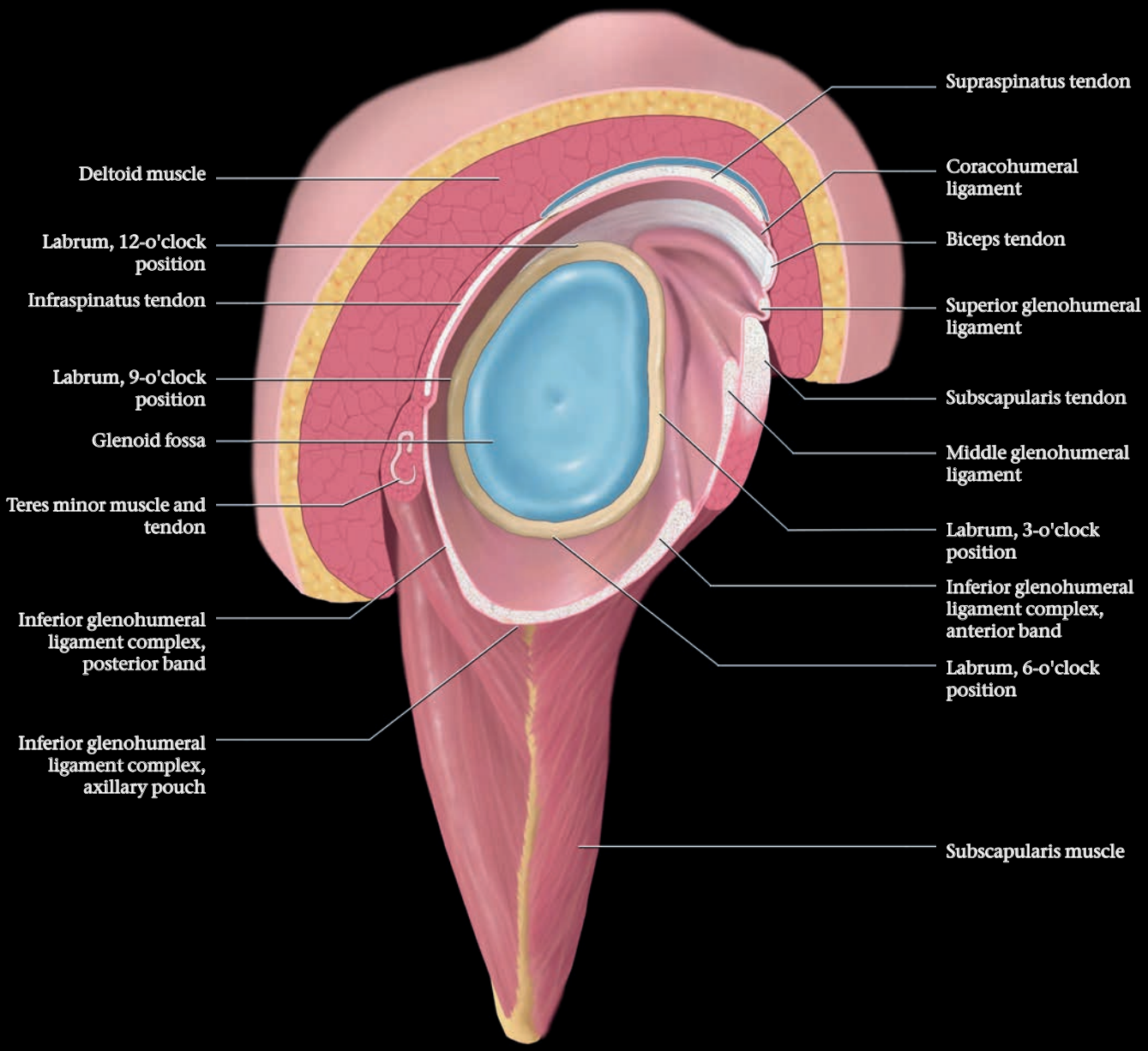




(Top) *Deep scapulohumeral dissection shows the course of the suprascapular nerve. The nerve enters the supraspinous fossa through the suprascapular notch, below the superior transverse scapular ligament. The nerve then passes beneath the supraspinatus, and curves around the lateral border of the spine of the scapula to enter the infraspinous fossa.* ***(Bottom)*** *Graphic shows the coronal section through the midportion of the shoulder joint. Note the subacromial-subdeltoid bursa is situated in the space between the deltoid, acromion, acromioclavicular joint, distal clavicle superiorly, and the supraspinatus tendon and muscle inferiorly. There is no direct communication between the bursa and glenohumeral joint unless there is full thickness tear of the supraspinatus tendon. The bursa is the main pain-producing structure around the shoulder. The wide expanse of the subacromial-subdeltoid bursa enables one to understand why shoulder symptoms are poorly localized. Patients often complain of generalized shoulder pain.*

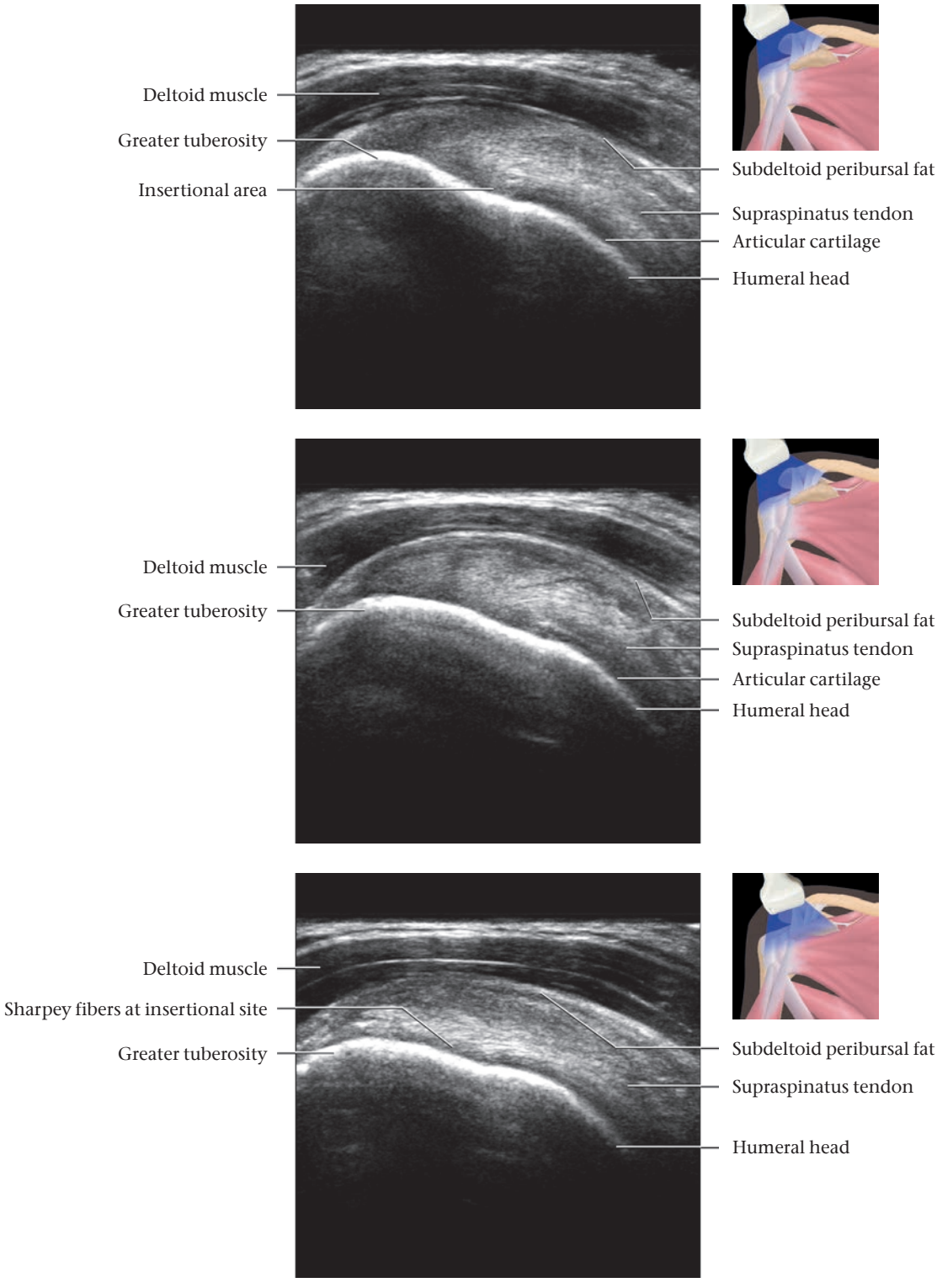
SHOULDER

SAGITTAL GRAPHIC, NORMAL LABRUM



Sagittal graphic shows the glenoid fossa. The labrum lines the edge of the glenoid, increasing the circumference and depth of the shoulder joint. The labrum plays an important role in stabilization of the shoulder joint. At the inferior aspect of the glenoid, the labrum is barely discernible. The superior, middle, and inferior glenohumeral ligaments are distinctive thickenings of the anterior shoulder capsule and cannot be seen as separate structures on ultrasound examination.

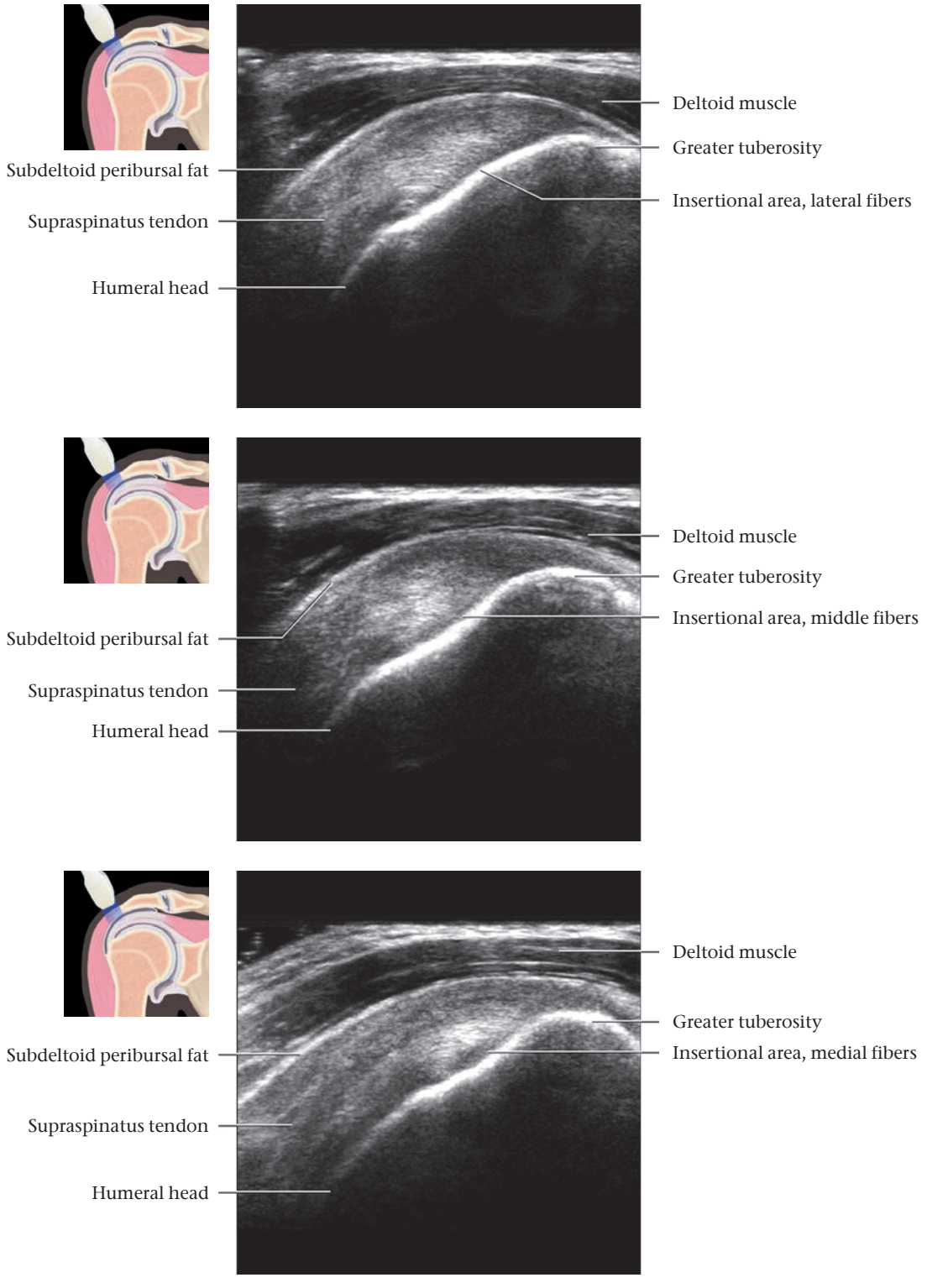
LONGITUDINAL US, SUPRASPINATUS INSERTIONAL AREA



(Top) *Longitudinal grayscale ultrasound shows the anterior fibers of the supraspinatus tendon insertional area. The supraspinatus tendon inserts over a wide area (footprint) on the anterior aspect of the greater tuberosity. Many tears of the supraspinatus tendon involve avulsion of the tendon from its insertional site.* ***(Middle)*** *Longitudinal grayscale ultrasound shows the supraspinatus tendon midfibers. There is often a thin hypoechoic line at the insertional area. This represents Sharpey fibers and fibrocartilage.* ***(Bottom)*** *Longitudinal grayscale ultrasound shows the supraspinatus tendon posterior fibers. The anterior, middle, and posterior fibers should be evaluated in turn.*

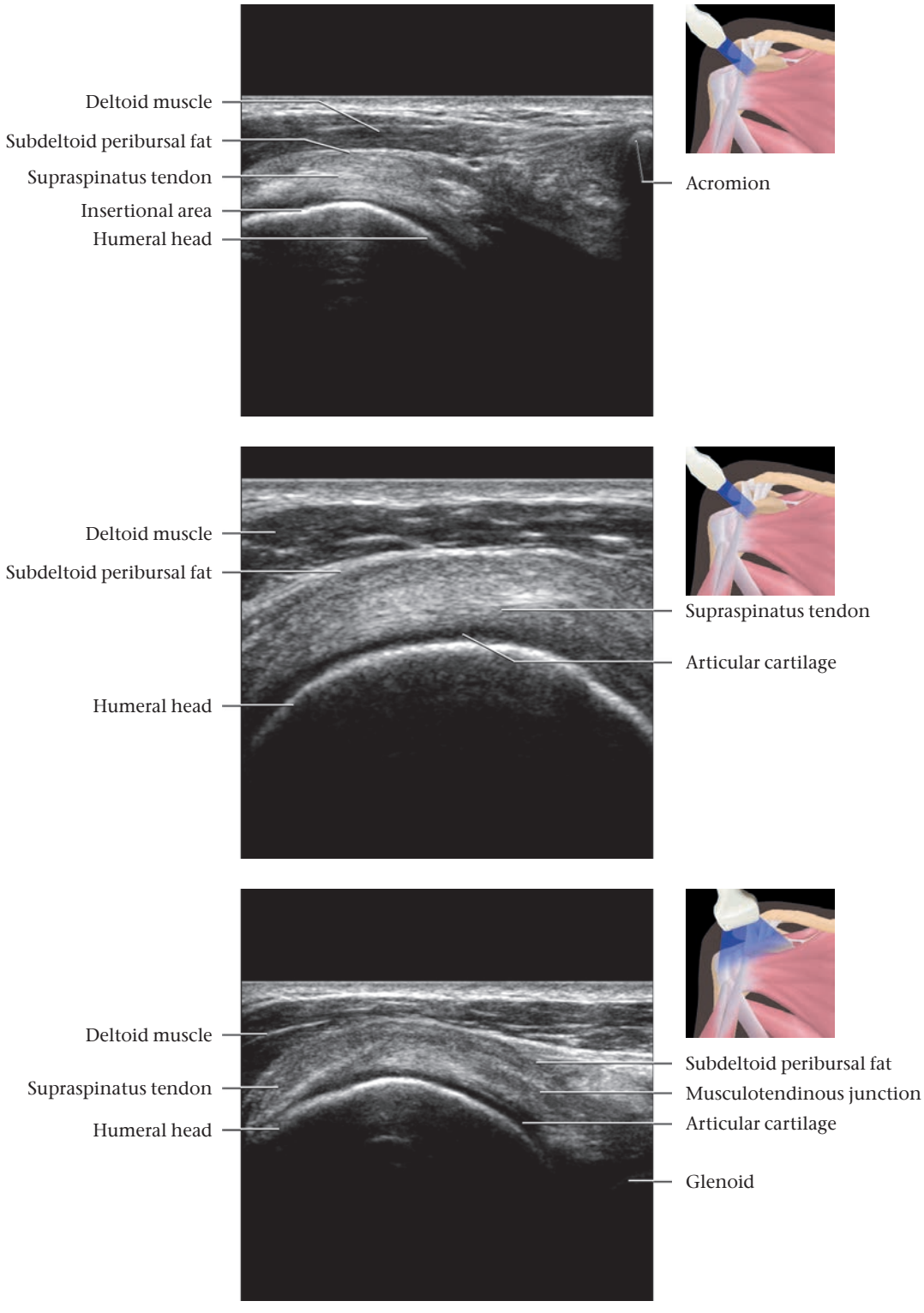
SHOULDER

TRANSVERSE US, SUPRASPINATUS INSERTIONAL AREA



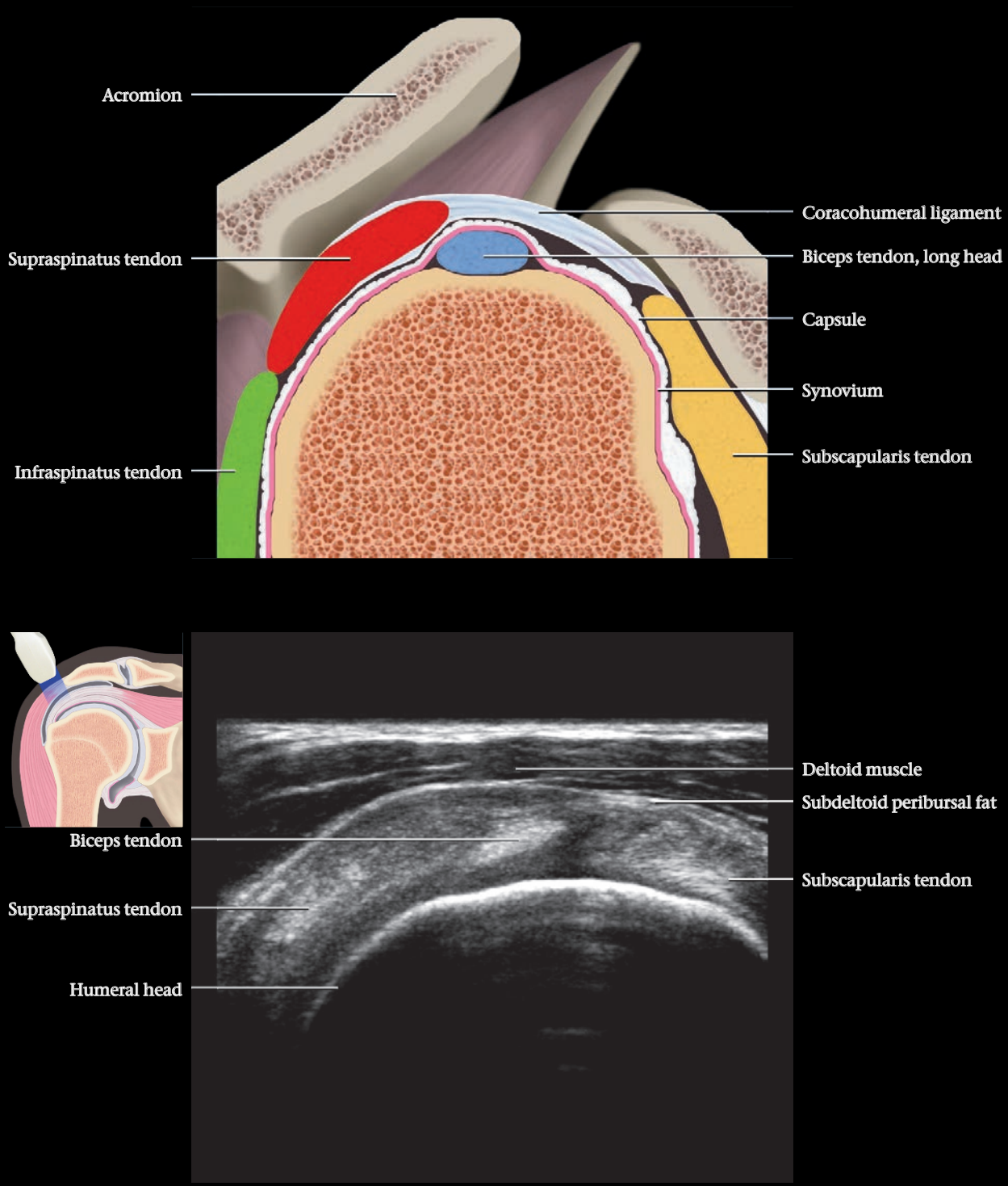
(Top) *Transverse grayscale ultrasound shows the supraspinatus tendon insertional area. Angulation and slight movement of the transducer will allow visualization of the lateral, middle, and medial fibers, respectively. The leading anterior edge of the supraspinatus is a common site of tear (rim rent tear).* ***(Middle)*** *Transverse grayscale ultrasound shows the supraspinatus tendon at the insertional area of midfibers. The fibrillar echotexture of the supraspinatus tendon can be seen but is prone to anisotropy.* ***(Bottom)*** *Transverse grayscale ultrasound shows the supraspinatus midfibers insertional area. Subdeltoid peribursal fat is variable in depth. The normal bursa cannot be depicted. It is seen only when distended with fluid or thickened due to synovitis.*

TRANSVERSE AND LONGITUDINAL US, SUPRASPINATUS



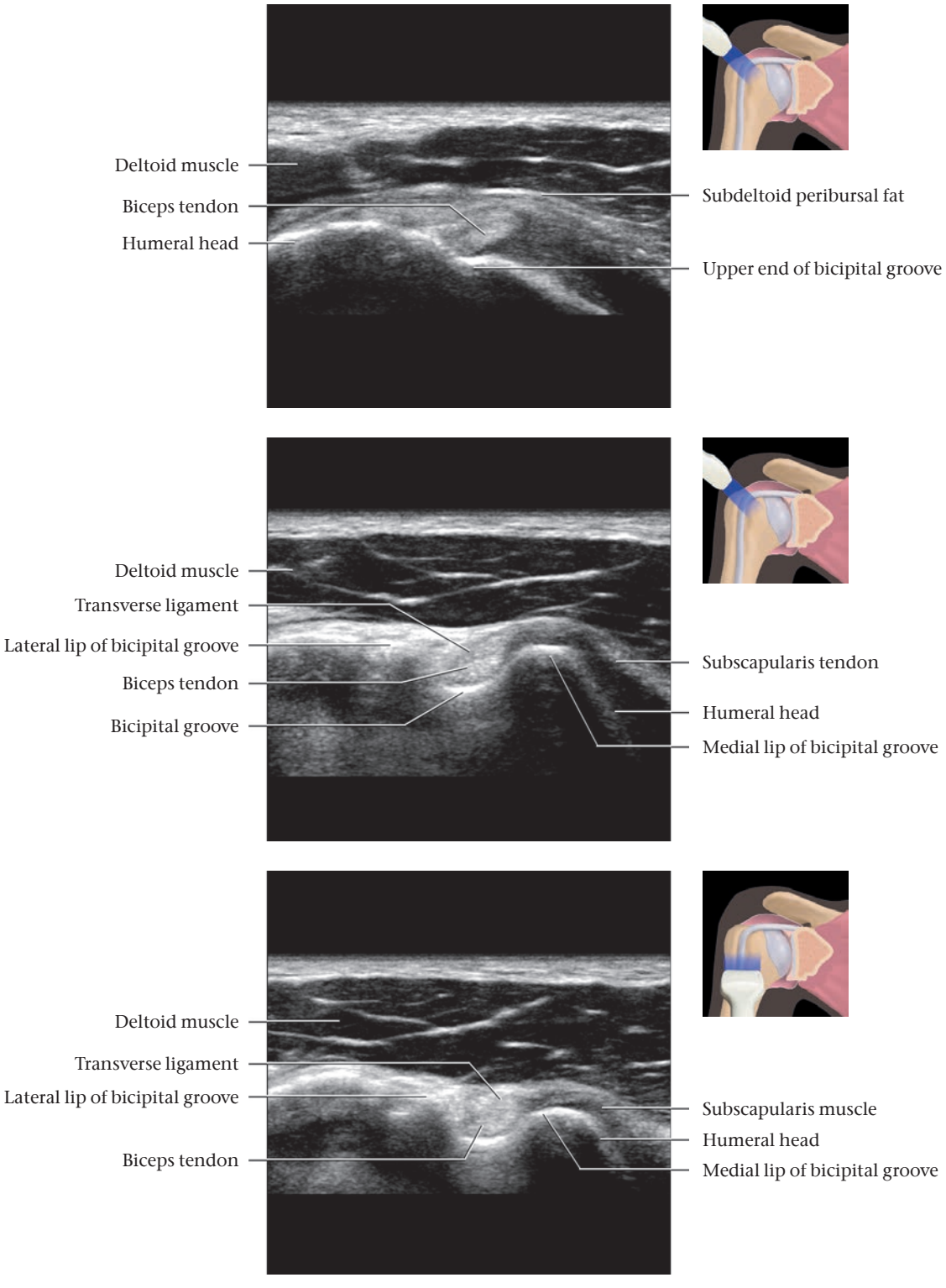
(Top) *Transverse grayscale ultrasound shows the supraspinatus tendon just medial to the insertional area. The critical zone is located just medial to the insertional area. This is a relatively hypovascular area. It is prone to calcific tendinosis and tears, though most tears tend to occur at the insertional site.* ***(Middle)*** *Transverse grayscale ultrasound shows the supraspinatus medial to the insertional area. The fibrillar pattern of the supraspinatus tendon is prone to anisotropy. With tendinosis, the fibrillar pattern is disrupted. The tendon becomes more hypoechoic and thickened.* ***(Bottom)*** *Longitudinal grayscale ultrasound shows the supraspinatus tendon at a slightly more medial aspect. Tears of the musculotendinous junction are relatively uncommon.*

GRAPHIC AND TRANSVERSE US, ROTATOR CUFF INTERVAL



(Top) *Graphic shows the relationship of the coracohumeral ligament to the rotator cuff tendons. The coracohumeral ligament is not a true ligament but a folded portion of the glenohumeral capsule that extends from the coracoid process to the humerus. The undersurface is lined by synovium. Portions of the coracohumeral ligament pass superficial and deep to the supraspinatus tendon. The coracohumeral ligament attaches to the superior border of the subscapularis tendon as well as to the greater tuberosity.* ***(Bottom)*** *Transverse grayscale ultrasound shows the shoulder at the rotator cuff interval. The rotator cuff interval represents the space between the leading anterior edge of the supraspinatus tendon and the adjacent superior edge of the subscapularis. It contains the biceps tendon. This should not be mistaken for a tear of the anterior aspect of the supraspinatus tendon. Patients with adhesive capsulitis may show increased hypoechogenicity and hyperemia of the rotator cuff interval as a result of inflammatory fibrovascular soft tissue overgrowth.*

TRANSVERSE US, BICEPS TENDON

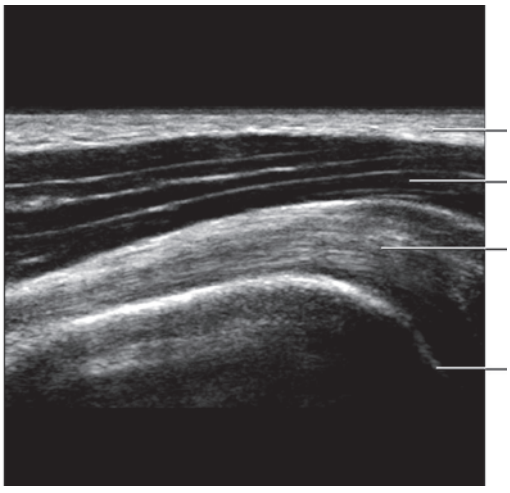


(Top) *Transverse grayscale ultrasound at the proximal aspect of the biceps tendon: The bicipital groove forms a fibroosseous tunnel for the biceps tendon. The normal biceps tendon has an ovoid configuration. With tendinosis, the tendon becomes larger and more rounded in appearance.* ***(Middle)*** *Transverse grayscale US shows the biceps tendon. The biceps tendon is held in position by the transverse ligament. The subscapularis tendon inserts into the lesser tuberosity, which forms the medial lip of the bicipital groove. The biceps tendon may sublux medially from the groove and may be associated with subscapularis tendon injury.* ***(Bottom)*** *Transverse grayscale US shows relations of the biceps tendon. The transverse ligament is not a distinct entity but consists of a fibrous expansion of both the pectoralis major tendon and subscapularis tendon inserting into the lateral lip of the bicipital groove.*

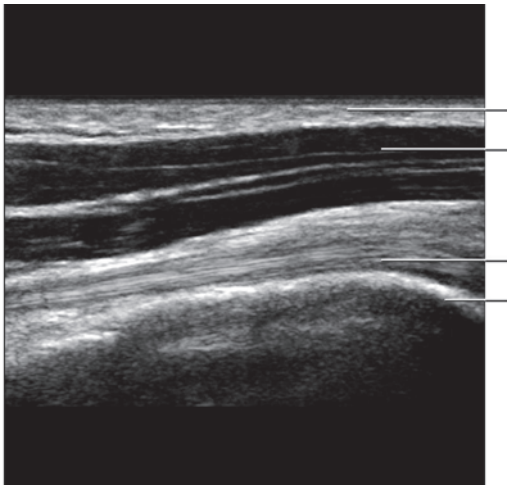
SHOULDER

LONGITUDINAL US, BICEPS TENDON

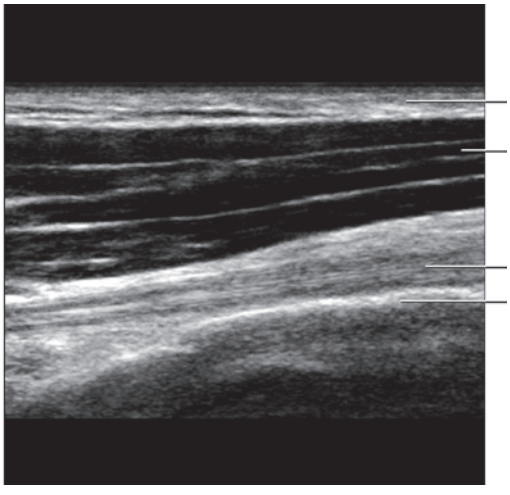






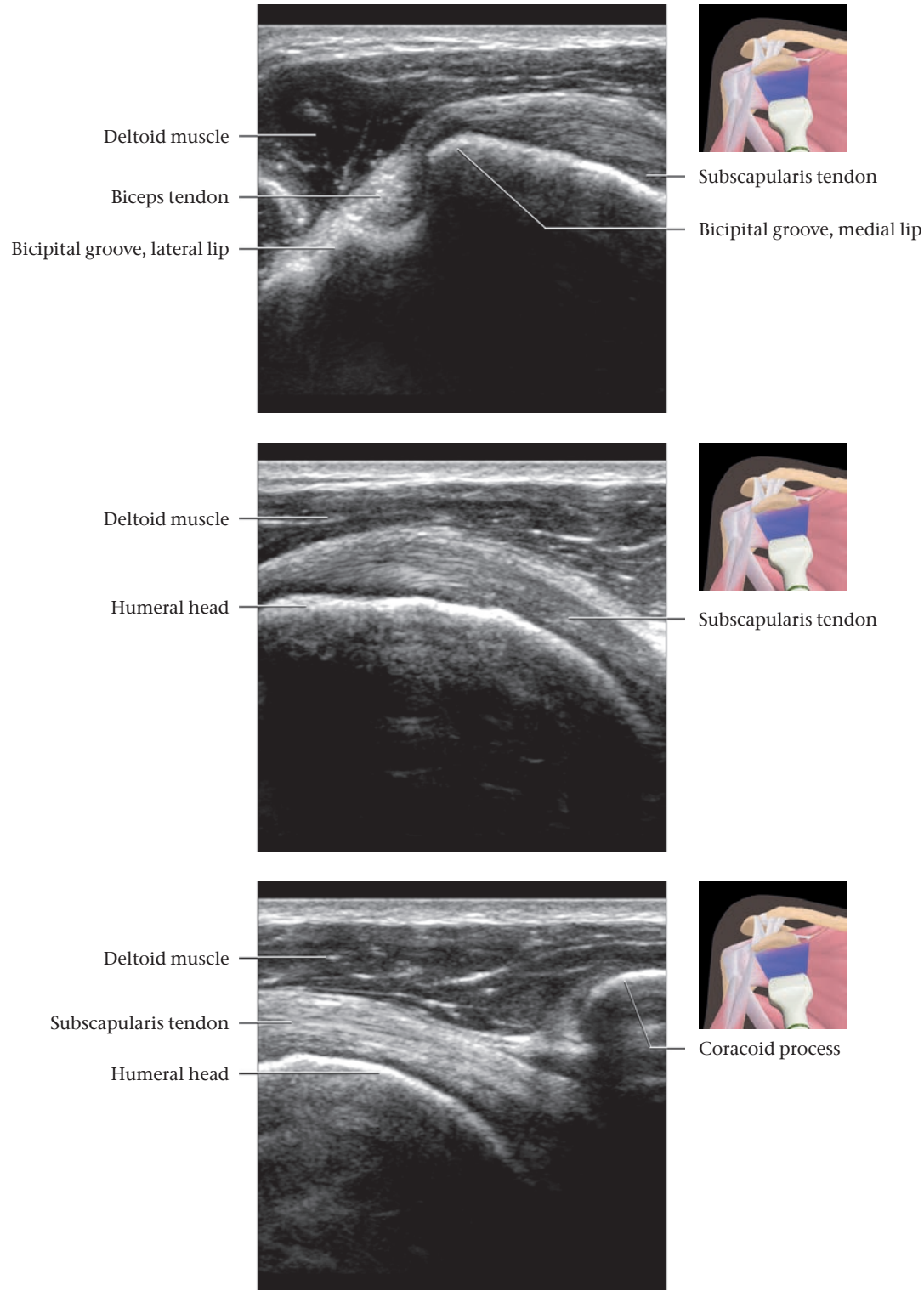






(Top) *Longitudinal grayscale ultrasound shows the uppermost section of the biceps tendon. The intraarticular portion of the biceps long head tendon cannot be fully depicted on longitudinal imaging. On longitudinal section, the biceps tendon seems to expand at its upper end as it becomes more ovoid in contour. This location is also the most common site of biceps tendinosis, which also manifests as enlargement of the biceps tendon.* ***(Middle)*** *Longitudinal grayscale ultrasound shows the upper section of the biceps tendon. A small amount of fluid in the biceps tendon sheath, which is continuous with the glenohumeral joint, is normal and should not be mistaken for tenosynovitis. No fluid is depicted in this image.* ***(Bottom)*** *Longitudinal grayscale ultrasound shows the lower aspect of the biceps tendon. Most incomplete tears of the biceps tendons are longitudinal in orientation and are best depicted on transverse imaging.*

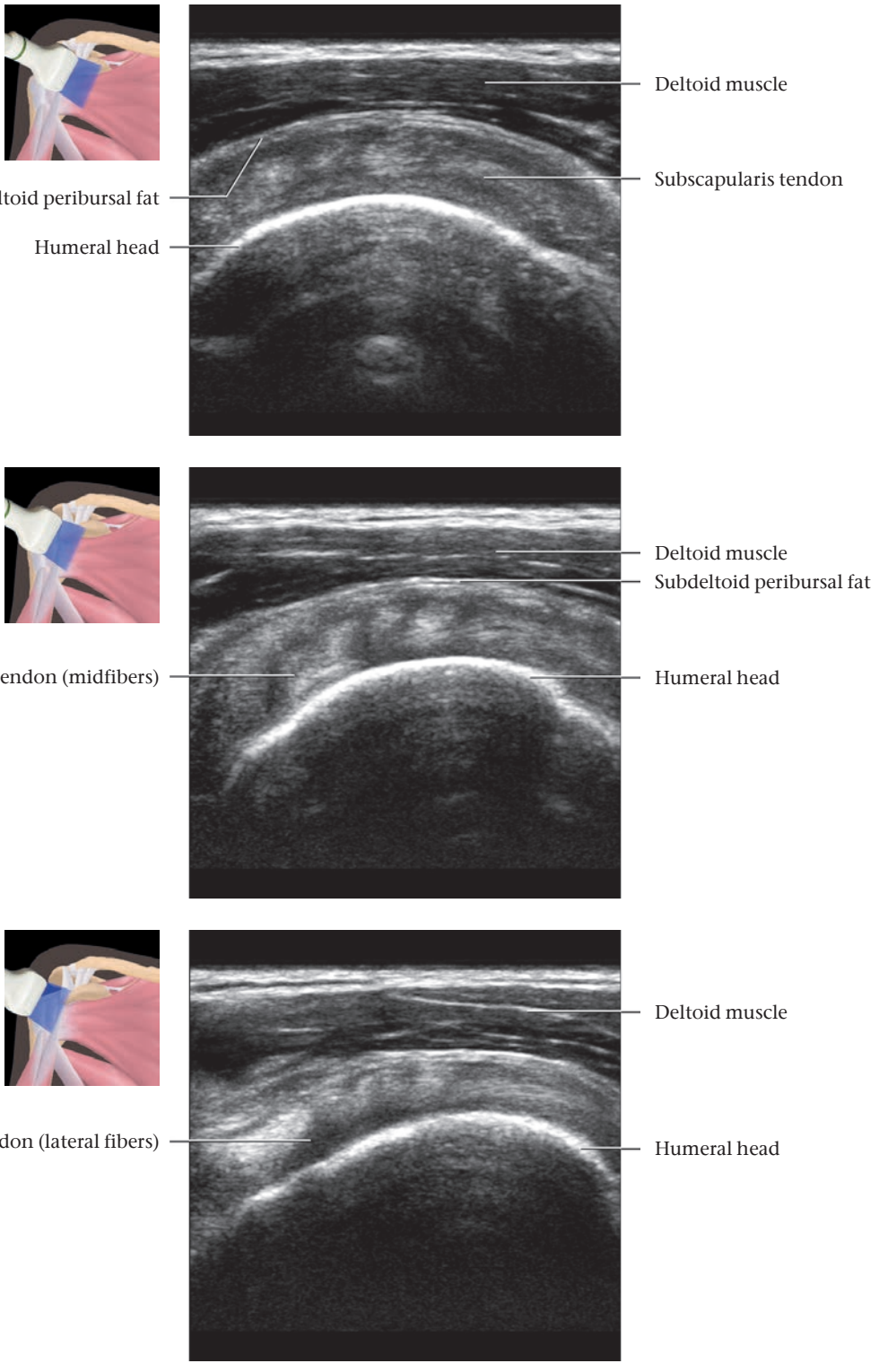
LONGITUDINAL, SUBSCAPULARIS



(Top) *Longitudinal grayscale ultrasound shows the subscapularis insertion. The subscapularis inserts into the medial lip of the bicipital groove but has a fibrous expansion traversing the biceps tendon, through which it also gains attachment to the lateral lip of the bicipital groove.* ***(Middle)*** *Longitudinal grayscale ultrasound shows the subscapularis insertional area. Complete tears of the subscapularis are uncommon and usually follow a severe traumatic event. Partial tears are more common and usually involve the superior edge of the tendon.* ***(Bottom)*** *Longitudinal grayscale ultrasound shows the subscapularis tendon. The subscapularis moves beneath the coracoid process during internal-external rotation. Impingement may potentially occur at this location (subcoracoid impingement).*

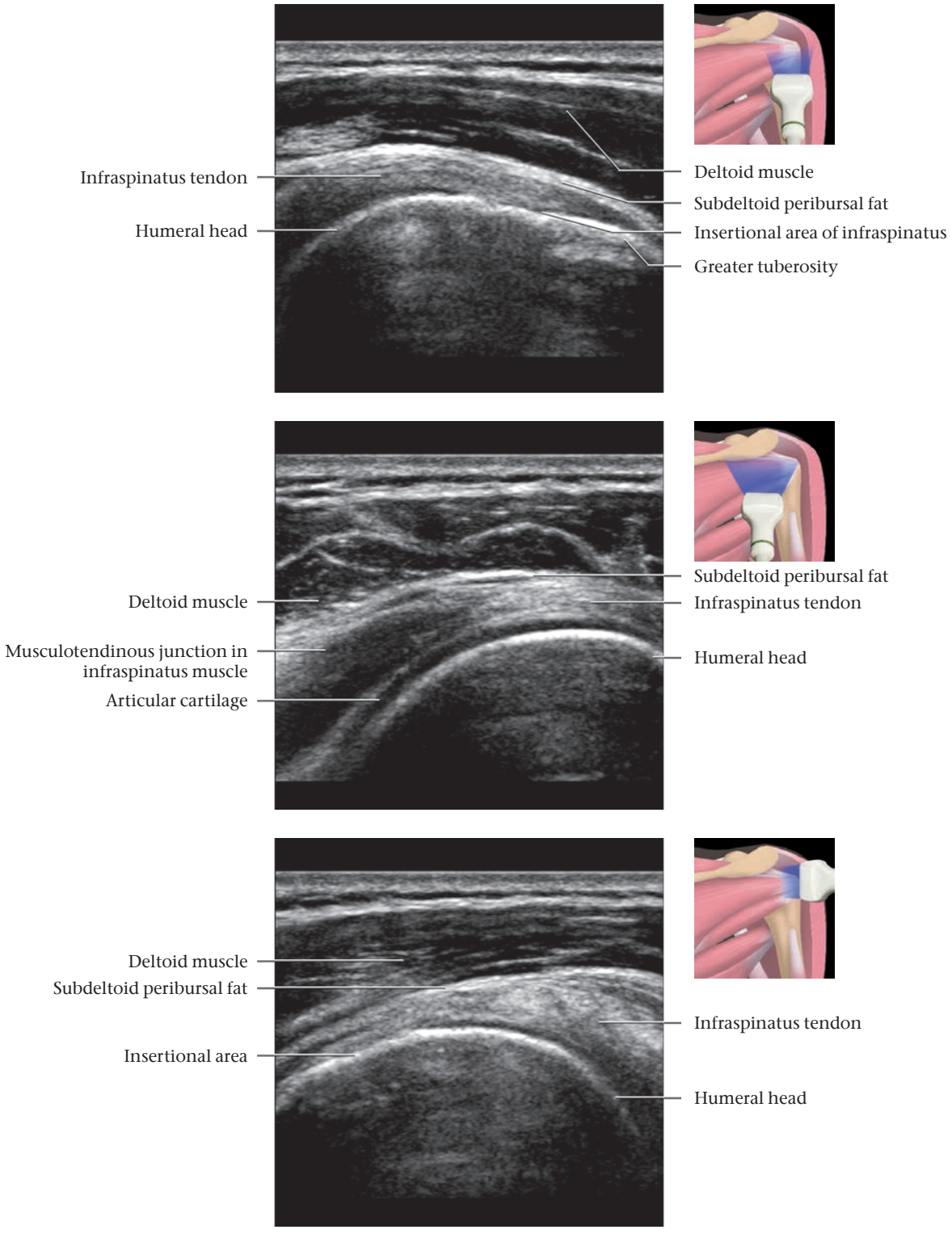
SHOULDER

TRANSVERSE US, SUBSCAPULARIS TENDON



(Top) *Transverse grayscale ultrasound shows the subscapularis tendon midfibers. As they converge toward the insertion, fiber bundles of the multipennate subscapularis tendon give the tendon a mixed echogenic appearance. This is normal and should not be mistaken for tendinosis.* ***(Middle)*** *Transverse grayscale ultrasound shows the subscapularis at the level of midfibers.* ***(Bottom)*** *Transverse grayscale ultrasound shows the subscapularis tendon. Tears of the subscapularis tendon usually occur just proximal to the insertional area. These tears may involve the fascial covering of the biceps tendon, facilitating biceps tendon dislocation.*

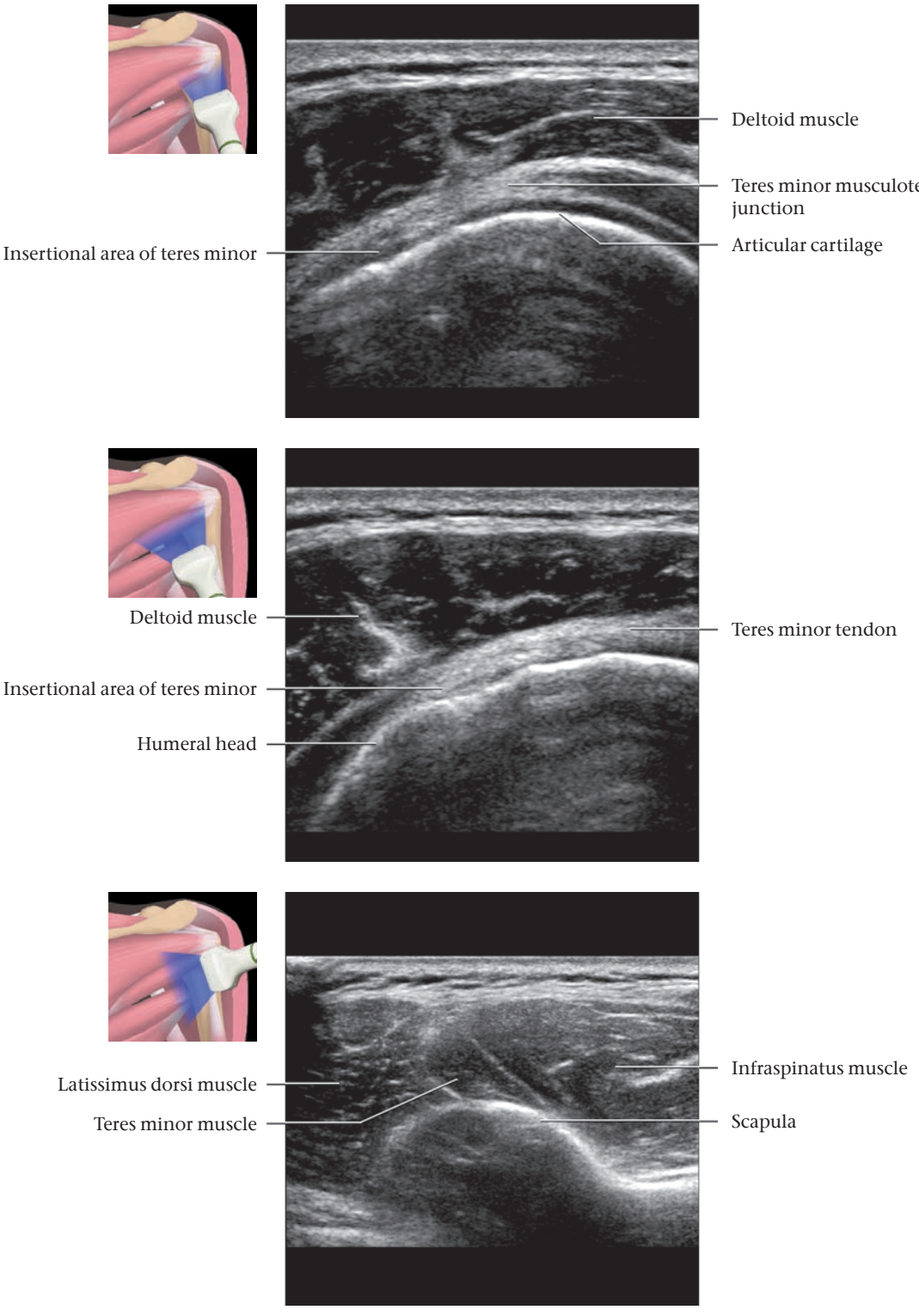
LONGITUDINAL AND TRANSVERSE US, INFRASPINATUS



(Top) *Longitudinal grayscale ultrasound shows the infraspinatus tendon insertional area. The infraspinatus tendon is less commonly torn than the supraspinatus tendon. Most tears are avulsive-type tears involving the insertional area.* ***(Middle)*** *Longitudinal grayscale ultrasound shows the infraspinatus musculotendinous junction. The muscle fibers interdigitate with the tendon at the musculotendinous junction and should not be mistaken for tears/tendinosis.* ***(Bottom)*** *Transverse grayscale ultrasound shows the infraspinatus insertional area. All tears of the rotator cuff tendons should be confirmed in both planes (transverse and longitudinal).*

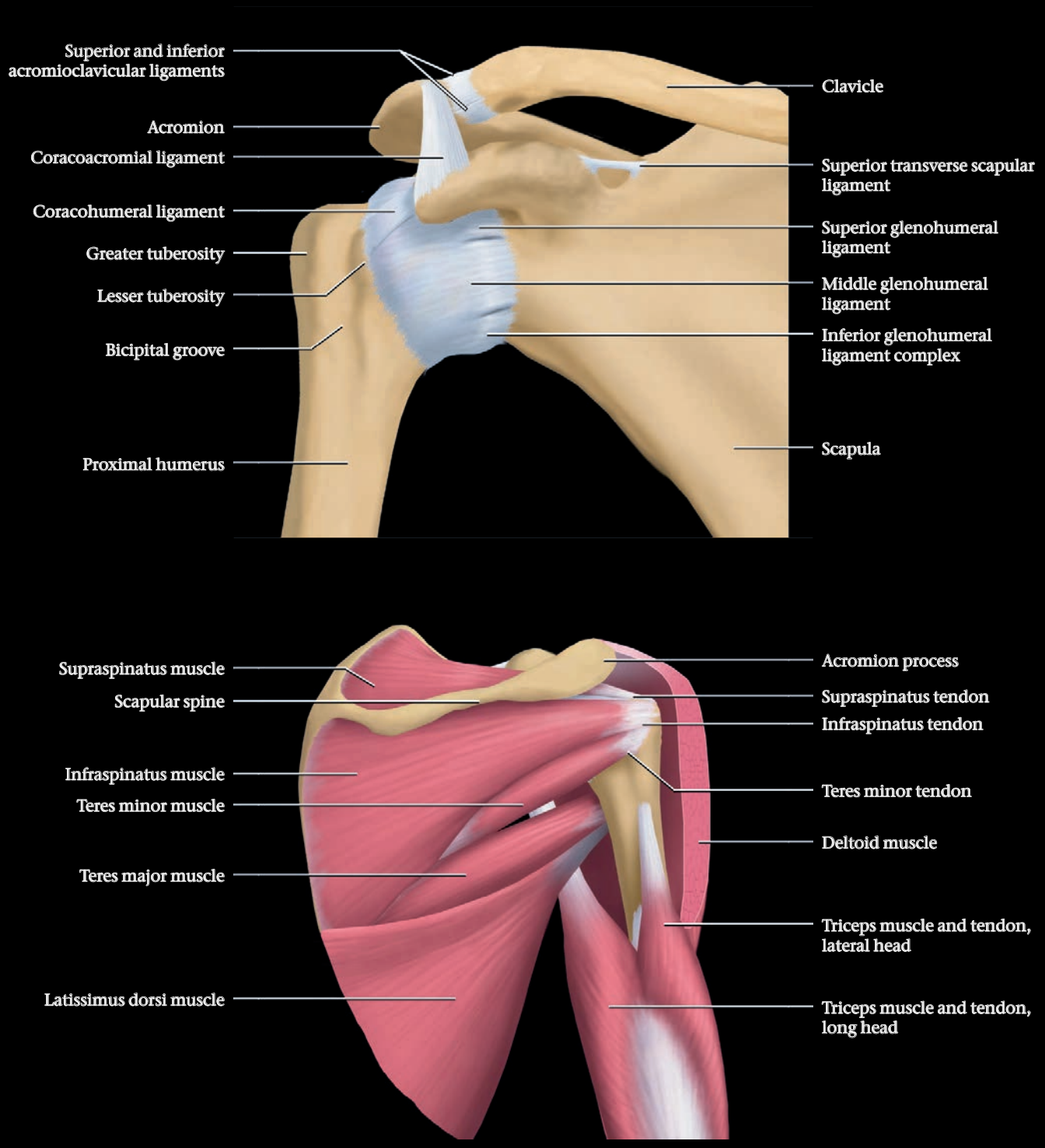
SHOULDER

LONGITUDINAL AND TRANSVERSE US, TERES MINOR



(Top) *Longitudinal grayscale ultrasound shows the teres minor muscle insertional area. The teres minor muscle is usually not torn in isolation, but it may be torn in massive rotator cuff tears. It is a small muscle and tendon seen at the posteroinferior edge of the infraspinatus tendon.* ***(Middle)*** *Longitudinal grayscale ultrasound shows the teres minor insertional area.* ***(Bottom)*** *Transverse grayscale ultrasound shows the teres minor. The teres minor muscle is best depicted on longitudinal imaging at the inferior aspect of the infraspinatus tendon. Isolated atrophy of the teres minor muscle can occur in quadrilateral space syndrome due to compression of the axillary nerve (part of the deltoid muscle may also be affected).*

GRAPHICS, SHOULDER JOINT AND POSTERIOR ASPECT

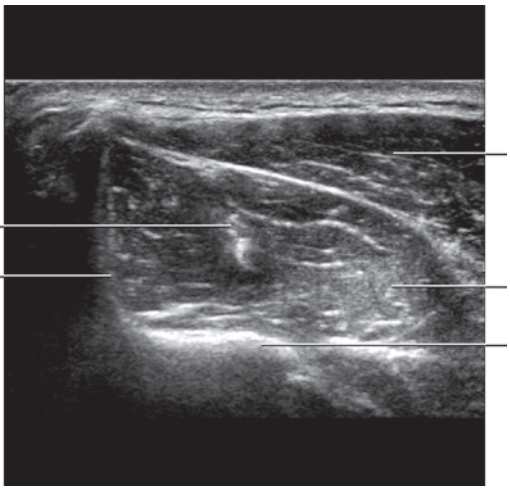


(Top) *Anterior graphic illustrates the right shoulder in deep dissection. The muscles have been removed.* ***(Bottom)*** *Posterior graphic illustrates the shoulder. Superficial scapulohumeral dissection demonstrates the musculature.*

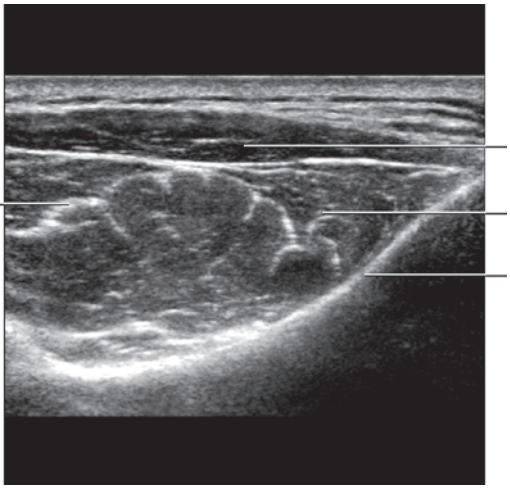
SHOULDER

LONGITUDINAL US, POSTERIOR ASPECT

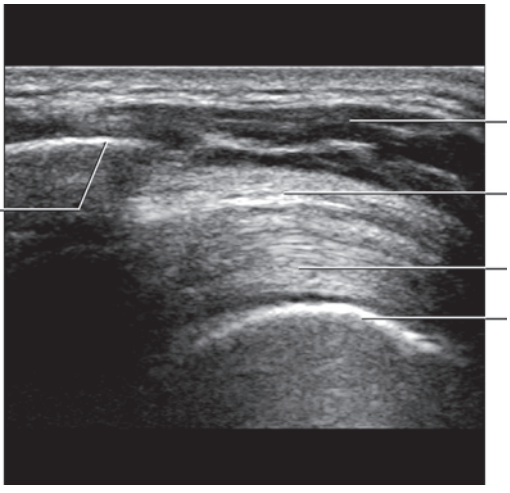






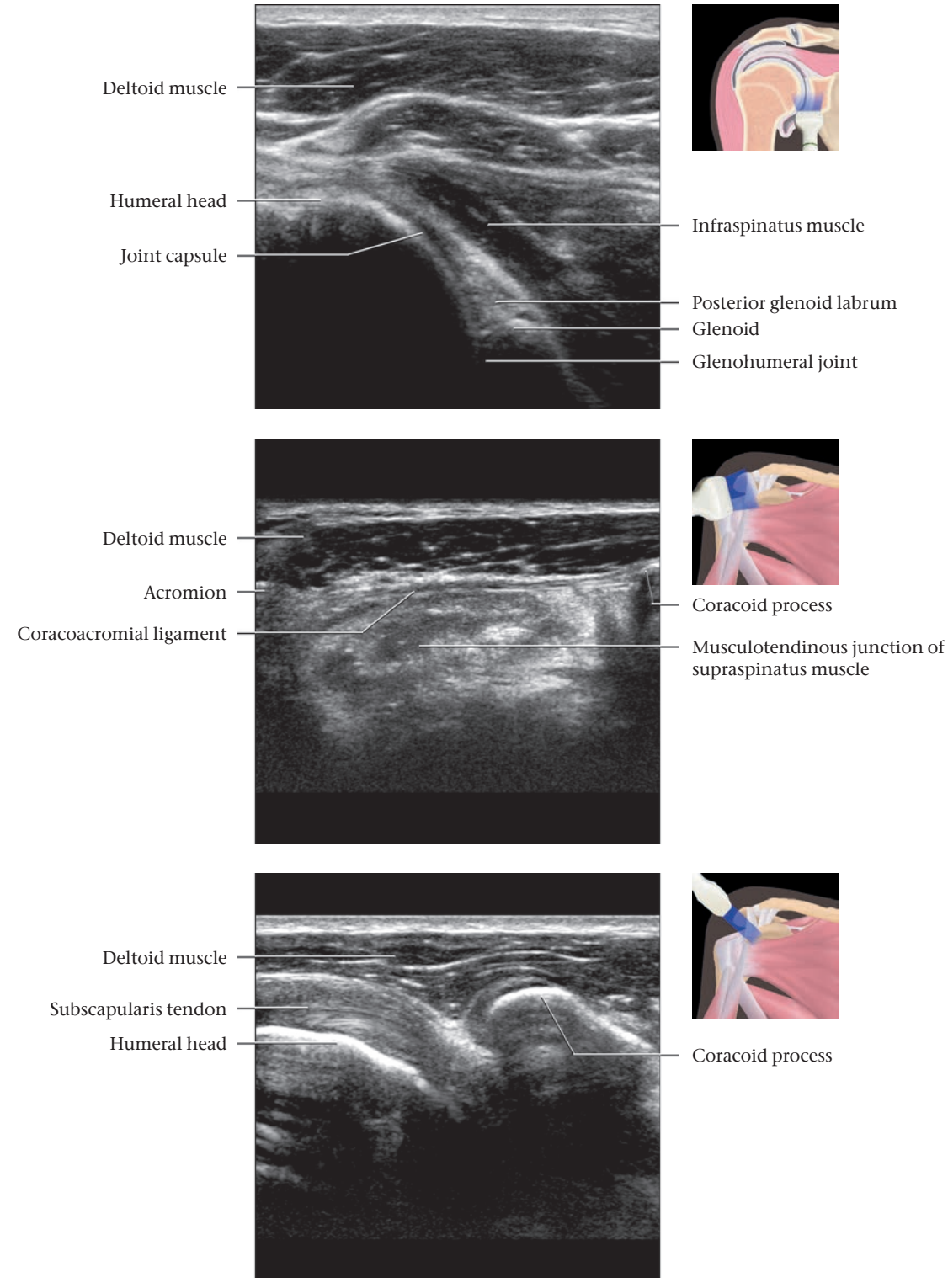






(Top) *Longitudinal grayscale US shows the posterior shoulder at the supraspinatus muscle. Muscle atrophy is common in rotator cuff pathology. US is almost as sensitive as MR in depiction of muscle atrophy. Atrophy is seen as reduction in muscle bulk with increase in muscle echogenicity. As a result, the central tendon is less readily seen.* ***(Middle)*** *Longitudinal grayscale US shows the shoulder on posterior view. Infraspinatus muscle atrophy usually accompanies supraspinatus muscle atrophy to a lesser or greater degree. Similar to the supraspinatus muscle, muscle bulk is reduced and becomes more echogenic with the central tendon becoming less easy to see.* ***(Bottom)*** *Longitudinal grayscale US shows the supraspinatus tendon. The supraspinatus tendon slides below the acromion during abduction. This relationship may be seen from either the anterior or posterior aspect of the shoulder. Dynamic imaging may reveal impingement of the supraspinatus against the acromion during abduction.*

LONGITUDINAL AND TRANSVERSE US, POSTERIOR GLENOID LABRUM AND GLENOHUMERAL JOINT



(Top) *Longitudinal grayscale ultrasound shows the posterior shoulder. The glenohumeral joint is most easily seen from the posterior aspect. This is a good site for ultrasound-guided joint injection. Joint effusions are also best seen in this area.* ***(Middle)*** *Longitudinal grayscale ultrasound shows the coracoacromial ligament. The coracoacromial ligament extends from the coracoid process to the anteroinferior margin of the acromion. Impingement of the supraspinatus tendon and the overlying subacromial-subdeltoid bursa may occur during shoulder abduction.* ***(Bottom)*** *Transverse grayscale ultrasound shows the coracoid process. The coracoid process is close to the humeral head and intervening subscapularis. Occasionally, the coracohumeral distance is reduced, and subcoracoid impingement may potentially occur.*

AXILLA

TERMINOLOGY

Definitions

- Fat-filled space between upper limb and thoracic wall

IMAGING ANATOMY

Extent

- Axilla is shaped like a pyramid with top layers shaved off
- Consists of apex, base, and 4 walls
  - Apex
    - Bounded by scapula, 1st rib, and mid 1/3 of clavicle
    - Arm communicates with posterior triangle of neck via apex of axilla
  - Anterior wall
    - Composed of pectoralis major and minor muscles
  - Posterior wall
    - Composed of teres major, latissimus dorsi, and subscapularis muscles
  - Medial wall
    - Composed of serratus anterior, upper ribs, and intercostal spaces
  - Lateral wall
    - Medial and lateral lips of bicipital groove into which anterior and posterior walls are inserted
  - Base
    - Composed of axillary fascia, subcutaneous fat, and skin
- Contents of axilla
  - Axillary artery and vein
  - Cords and branches of brachial plexus
  - Coracobrachialis and biceps muscles
  - Lymph nodes and vessels
  - Fat
- Axillary artery
  - Continuation of subclavian artery
  - Lies on posterior wall of axilla
  - Surrounded by cords and branches of brachial plexus
  - Vein lies medial to artery
  - Arterial branches
    - Superior thoracic artery
    - Acromiothoracic artery
    - Lateral thoracic artery
    - Subscapular artery
    - Anterior and posterior circumflex humeral arteries
- Axillary vein
  - Continuation of brachial vein
    - Tributaries correspond to branches of axillary artery and also cephalic vein
- Brachial plexus
  - Cord and terminal branches of brachial plexus pass through axilla
  - 3 cords: Lateral, medial, and posterior
  - Lateral cord gives rise to
    - Lateral pectoral nerve
    - Musculocutaneous nerve: Pierces coracobrachialis to descend down arm between biceps and brachialis muscles
    - Contributes to median nerve
  - Medial cord gives rise to
    - Medial pectoral nerve
    - Ulnar nerve
    - Contributes to median nerve
    - Medial cutaneous nerves of arm and forearm
  - Posterior cord gives rise to
    - Subscapular nerve
    - Thoracodorsal nerve
    - Axillary nerve, which passes through quadrilateral space posteriorly around surgical neck of humerus, accompanied by posterior circumflex humeral artery
    - Radial nerve

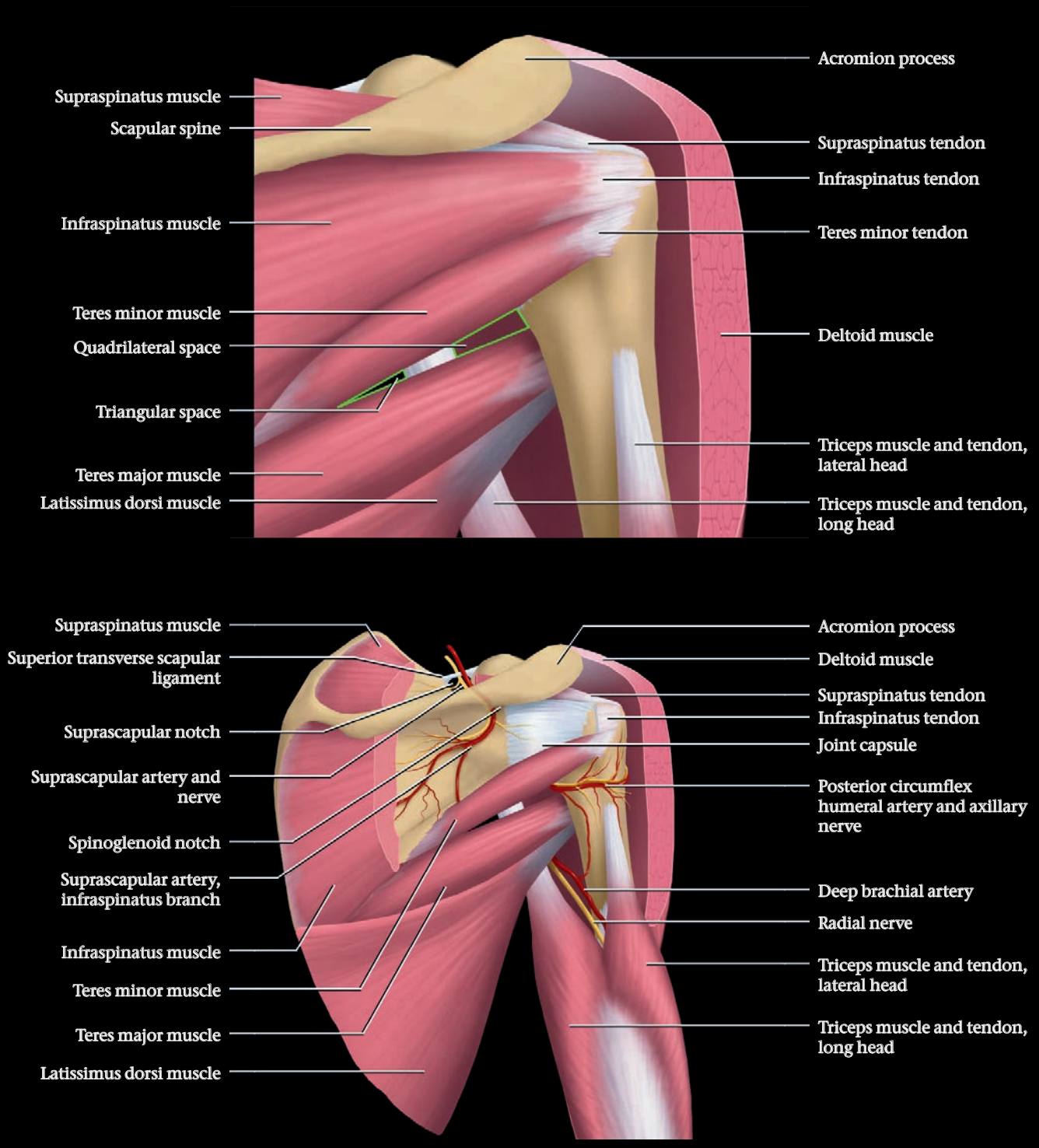
Anatomy Relationships

- **Quadrilateral space**
  - Superior border: Teres minor muscle
  - Inferior border: Teres major muscle
  - Lateral border: Surgical neck of humerus
  - Medial border: Long head of triceps muscle
  - Contents: Axillary nerve and posterior circumflex humeral artery
    - Axillary nerve supplies teres minor muscle, deltoid muscle, posterolateral cutaneous region of shoulder and upper arm
- **Triangular space**
  - Located medial to quadrilateral space
  - Superior border: Teres minor muscle
  - Inferior border: Teres major muscle
  - Lateral border: Long head of triceps muscle
  - Contents: Circumflex scapular artery
    - Branch of subscapular artery supplying infraspinatus fossa

ANATOMY IMAGING ISSUES

Questions

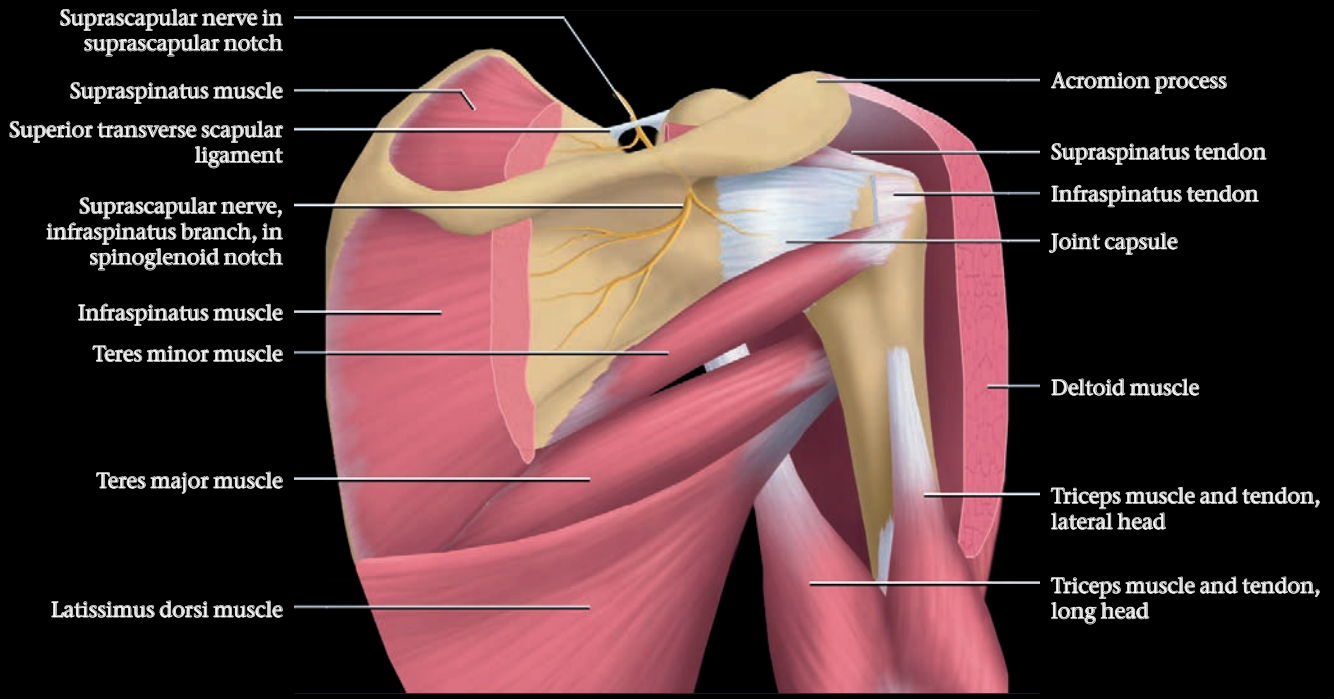
- Quadrilateral space syndrome = neurovascular compression syndrome due to compression of axillary nerve or posterior humeral circumflex artery in quadrilateral space
  - Can have complications that are purely neurologic, purely vascular, or both
  - Effects
    - Point tenderness of quadrilateral space
    - Poorly localized shoulder pain ± paresthesia radiating top lateral arm
    - Symptoms aggravated by abduction and external rotation of arm
    - Teres minor ± deltoid atrophy
    - Intermittent ischemic-type pain
  - Due to
    - Humeral fracture
    - Fibrous bands secondary to trauma
    - Muscle hypertrophy ± fibrotic bands seen in throwing athletes, tennis players, or volleyball players
    - Paralabral cysts: Most common cause of mass in this region, high associations with labral tears
    - Glenohumeral joint dislocation
    - Extreme or prolonged abduction of arm during sleep

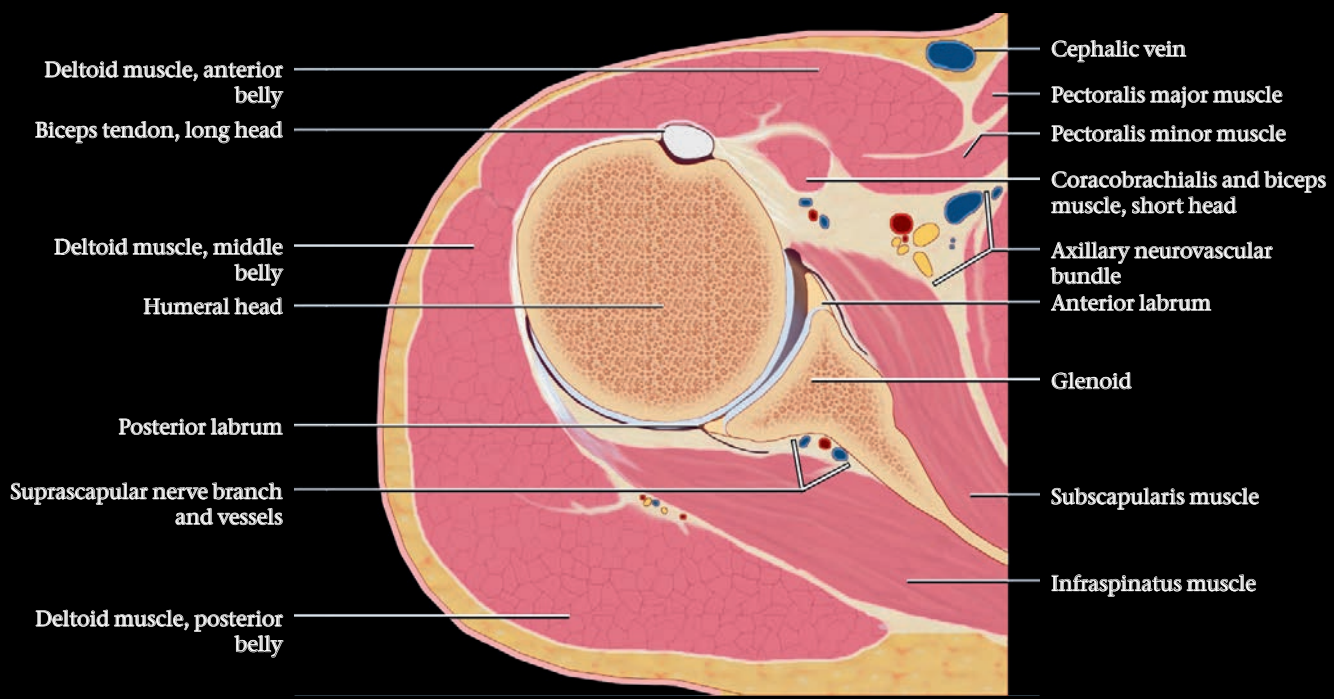


***(Top)** Posterior graphic shows the shoulder. Superficial scapulohumeral dissection shows the location of the quadrilateral space and triangular space (each outlined in green). The quadrilateral space transmits the axillary nerve and the posterior circumflex humeral artery while the much less important triangular space transmits the scapular circumflex vessels. **(Bottom)** Graphic of the deep scapulohumeral dissection shows the major neurovascular structures, including those in the quadrilateral space.*

AXILLA

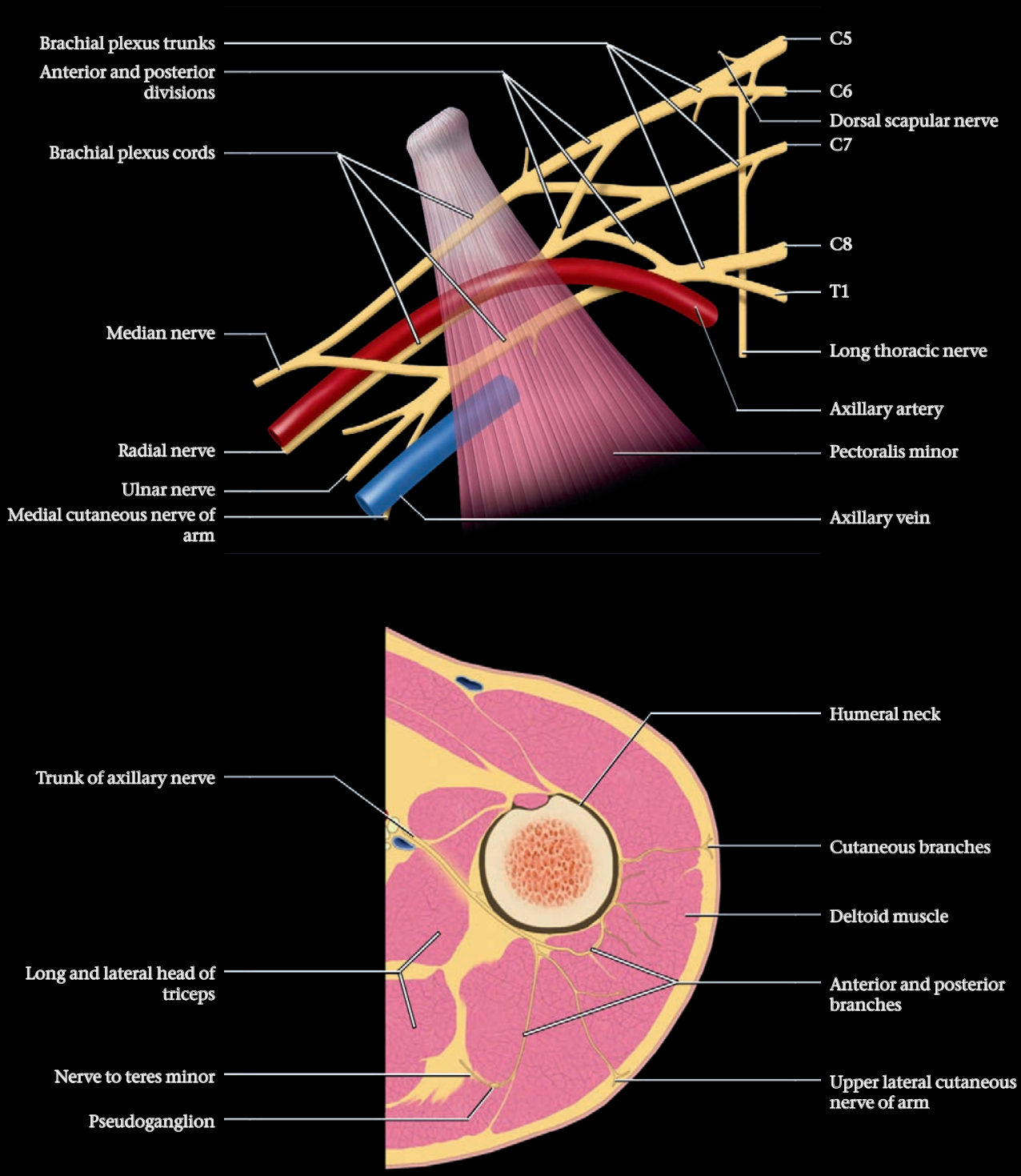
GRAPHICS, DEEPER STRUCTURES





(Top) *Graphic of deep scapulohumeral dissection shows the course of the suprascapular nerve.* ***(Bottom)*** *Axial graphic shows the location of the suprascapular artery, nerve, and vein branches, just below the level of the spinoglenoid notch. The suprascapular nerve is a mixed motor and sensory nerve. It arises from the anterior rami of the C5 and C6 roots. It passes deep to the superior transverse scapular ligament of the suprascapular notch. It then passes deep to the inferior transverse scapular ligament of the spinoglenoid notch. It supplies the supraspinatus and the infraspinatus muscles with sensory fibers to the acromioclavicular (AC) joint and the glenohumeral joint capsules.*

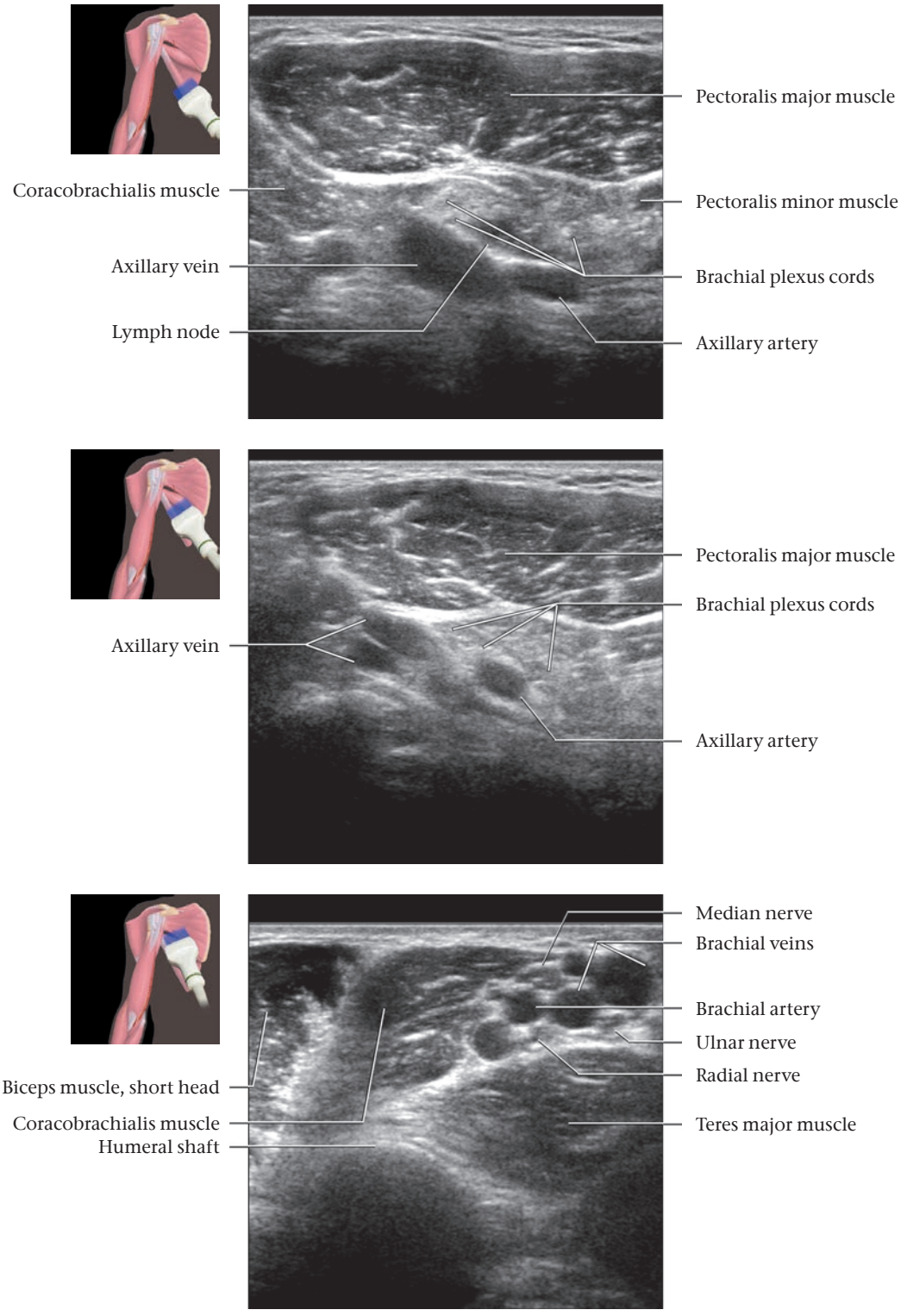
GRAPHICS, RELATIONS OF NEUROVASCULAR STRUCTURES



*(**Top**) Graphic shows relations of the brachial plexus in the axilla. The brachial plexus arises from the anterior rami of the C5, C6, C7, C8, and T1 nerves. They first unite to form the superior, middle, and inferior trunks. The trunks then divide and reunite to form the lateral, posterior, and middle cords. Beyond the lateral margin of the pectoralis minor muscle, they continue as the terminal branches of the plexus (axillary, musculocutaneous, radial, medial, and ulnar nerves). **(Bottom)** Graphic shows a section through the upper arm with the axiliary nerve and its branches.*

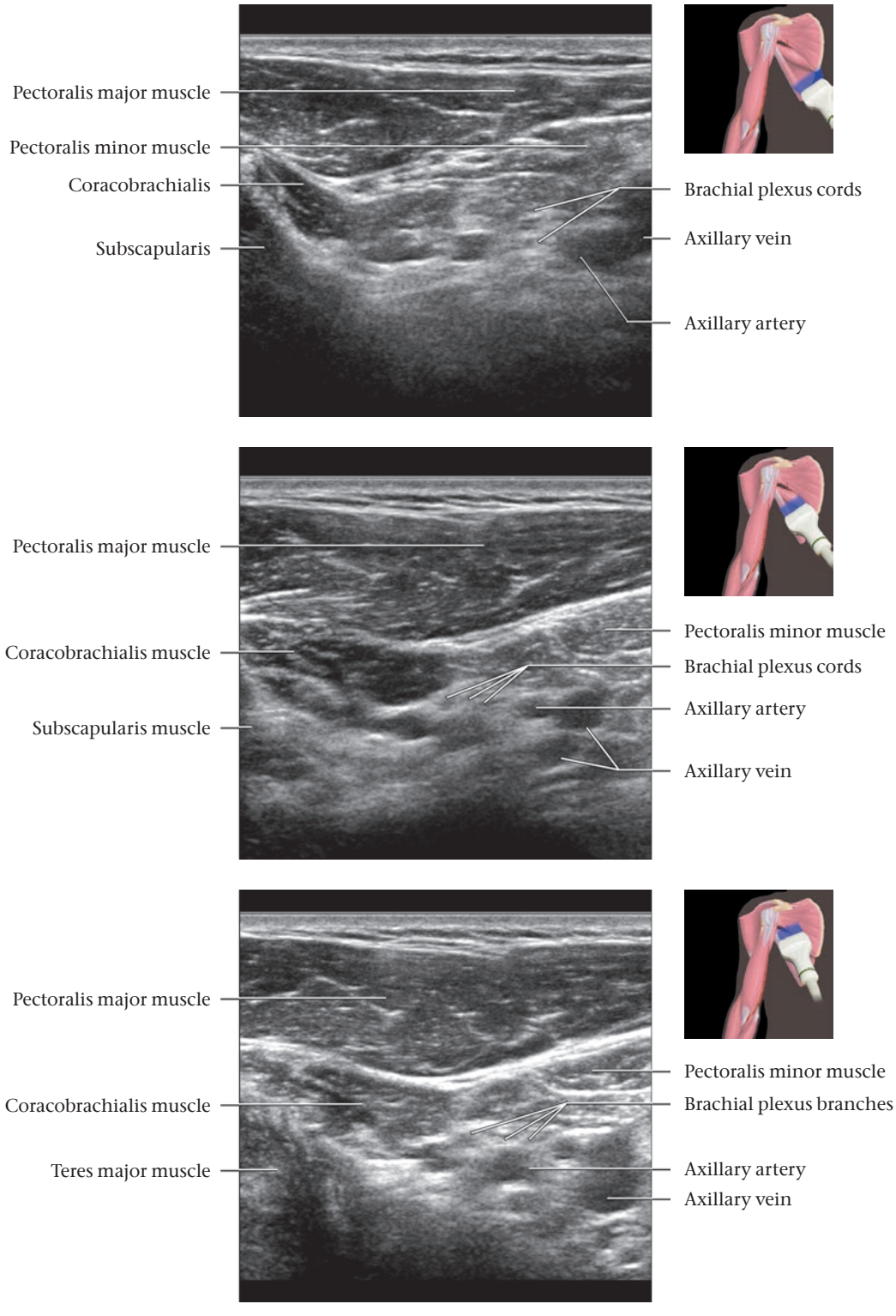
AXILLA

TRANSVERSE US, AXILLA



(Top) *Transverse grayscale ultrasound shows the proximal axilla with the arm abducted. The contents of the axilla are inspected with the arm fully abducted.* ***(Middle)*** *Transverse grayscale ultrasound shows the midportion of the axilla. The axillary artery and vein pass through the axilla surrounded by the cords of the brachial plexus. The cords (medial, lateral, and posterior) are named relative to their position alongside the axillary artery. Lymph nodes with variably fatty hila are commonly seen in the axilla around the neurovascular bundle.* ***(Bottom)*** *Transverse grayscale ultrasound shows the distal aspect of the axilla.*

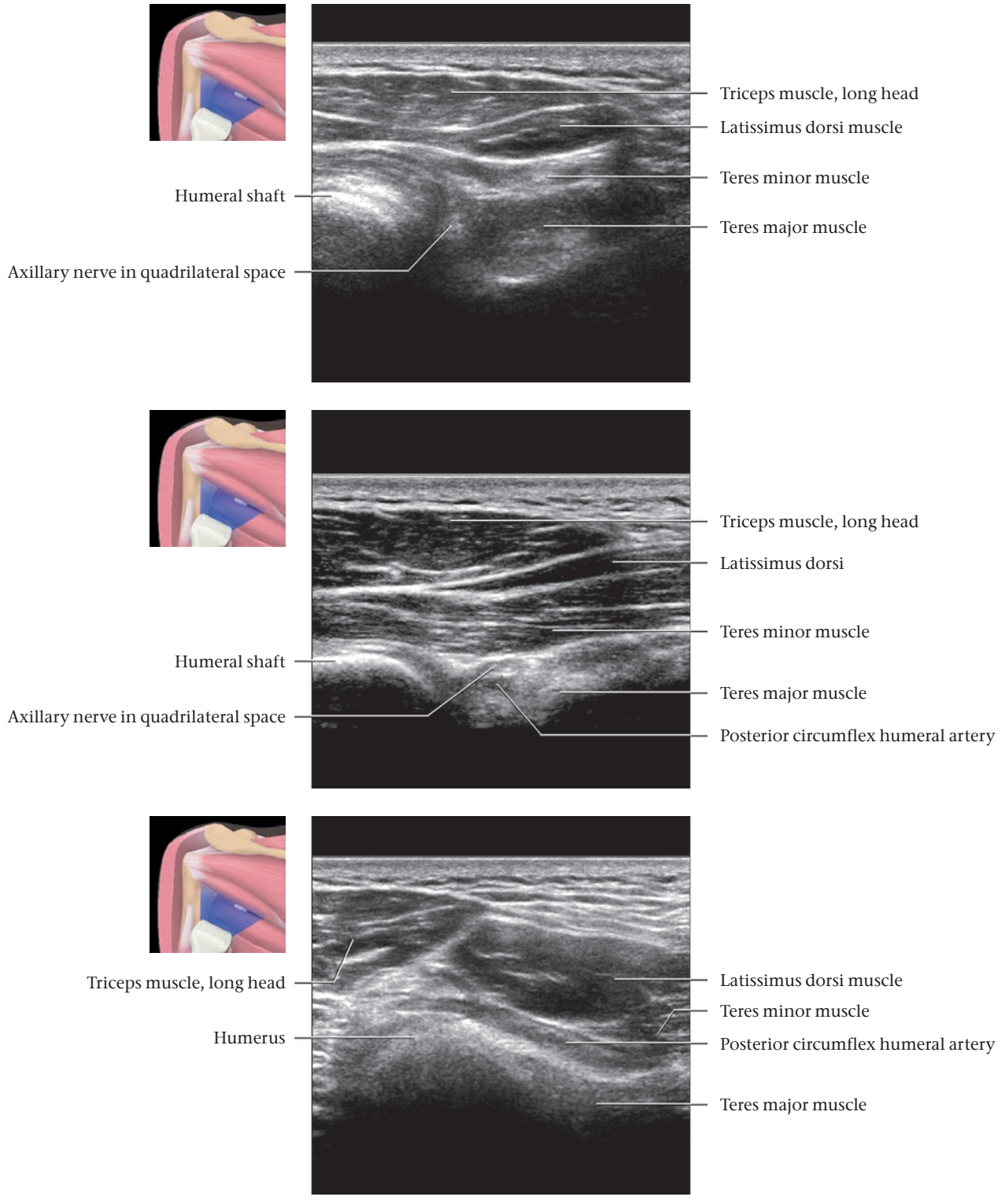
TRANSVERSE US, ANTERIOR AXILLARY WALL



(Top) *Transverse grayscale ultrasound shows the proximal anterior wall of the axilla. The anterior wall of the axilla can be examined with the arm by the side.* ***(Middle)*** *Transverse grayscale ultrasound shows the midsection of the anterior wall of the axilla. The anterior wall of the axilla is formed by the pectoralis major and pectoralis minor muscles.* ***(Bottom)*** *Transverse grayscale ultrasound shows the distal anterior wall of axilla.*

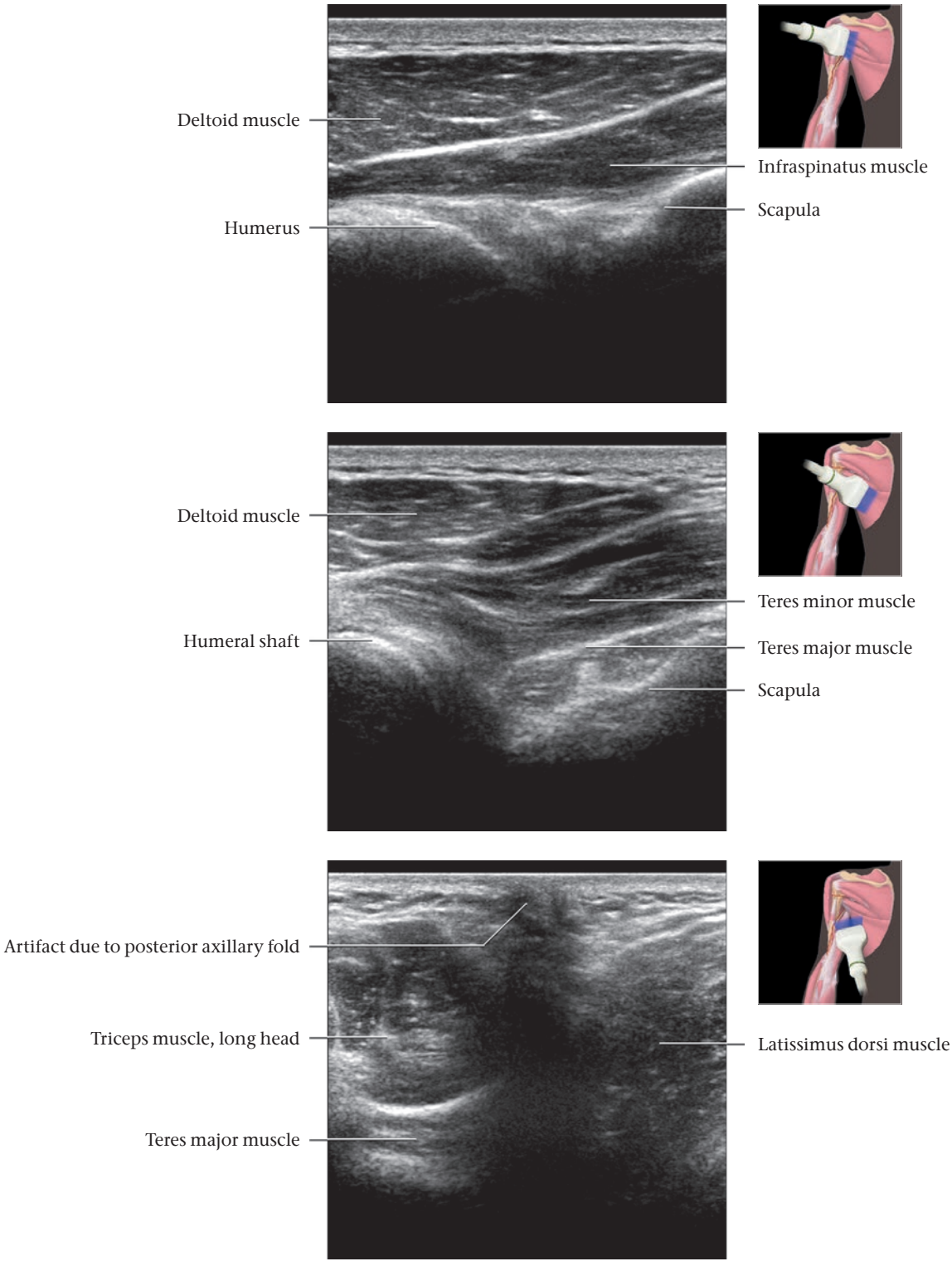
AXILLA

TRANSVERSE US, QUADRILATERAL SPACE



(Top) *Transverse grayscale ultrasound of the arm shows the anterior aspect of the quadrilateral space (quadrangular space) with the arm abducted. This space contains the axillary nerve and posterior circumflex humeral vessels.* ***(Middle)*** *Transverse grayscale ultrasound shows the quadrilateral space with the arm adducted. The contents of the space are more easily seen with the arm adducted.* ***(Bottom)*** *Transverse grayscale ultrasound in the more posterior position of the arm shows the posterior circumflex humeral artery posterior to the quadrilateral space.*

TRANSVERSE US, POSTERIOR AXILLARY WALL



(Top) *Transverse grayscale ultrasound shows the upper aspect of the posterior axillary wall.* ***(Middle)*** *Transverse grayscale ultrasound shows the middle aspect of the posterior wall of the axilla. The posterior wall of the axilla is composed of the teres major, latissimus dorsi, and subscapularis muscles.* ***(Bottom)*** *Transverse grayscale ultrasound shows the lowermost aspect of the axilla.*

ARM

IMAGING ANATOMY

Overview

- Muscles of upper arm are divided into anterior and posterior compartments

Anatomy Relationships

- **Anterior compartment of arm**
  - Coracobrachialis muscle
    - Origin: Coracoid process tip, in common with and medial to short head biceps tendon
    - Insertion: Medial surface of humeral midshaft, between brachialis and triceps muscle origins
    - Nerve supply: Musculocutaneous nerve, perforates muscle
    - Blood supply: Brachial artery, muscular branches
    - Action: Flexes and adducts shoulder, supports humeral head in glenoid
  - Biceps muscle, short head
    - Origin: Coracoid process tip, in common with and lateral to coracobrachialis tendon
    - Insertion: Radial tuberosity after joining long head
    - Nerve supply: Musculocutaneous nerve
    - Blood supply: Brachial artery, muscular branches
    - Action: Flexes elbow and shoulder, supinates forearm
  - Biceps muscle, long head
    - Origin: Predominantly supraglenoid tubercle; also superior glenoid labrum and coracoid base
    - Insertion: Radial tuberosity after joining with short head
    - Tendon runs along the bicipital groove, which is covered by transverse ligament
    - Transverse ligament spans proximal end of bicipital groove and comprises a deeper layer formed from subscapularis tendon fibers and a superficial fibrous layer in continuity with supraspinatus tendon and coracohumeral ligament
    - Nerve supply: Musculocutaneous nerve
    - Blood supply: Brachial artery, muscular branches
    - Action: Flexes elbow, supinates forearm
    - Variants, biceps muscle: 3rd head in 10% arising at upper medial aspect of brachialis muscle; 4th head can arise from lateral humerus, bicipital groove, or greater tuberosity
  - Brachialis muscle
    - Origin: Distal 1/2 of anterior humeral shaft and 2 intermuscular septa
    - Insertion: Tuberosity of ulna and anterior surface of coronoid process
    - Nerve supply: Musculocutaneous nerve plus branch of radial nerve
    - Blood supply: Brachial artery, muscular branches, and recurrent radial artery
    - Action: Flexes forearm
    - Covers anterior aspect of elbow joint
- **Posterior compartment of arm**
  - Triceps muscle, long head
    - Origin: Infraglenoid tubercle of scapula
    - Insertion: Proximal olecranon and deep fascia of arm after joining with lateral and medial heads
    - Nerve supply: Radial nerve
    - Blood supply: Deep brachial artery branches
    - Action: Elbow extension, adducts humerus when arm is extended
  - Triceps muscle, lateral head
    - Origin: Posterior and lateral humeral shaft, lateral intermuscular septum
    - Insertion: Proximal olecranon and deep fascia of arm after joining with long and medial heads
    - Nerve supply: Radial nerve
    - Blood supply: Deep brachial artery branches
    - Action: Elbow extension
  - Triceps muscle, medial head
    - Origin: Posterior humeral shaft from teres major insertion to near trochlea, medial intermuscular septum
    - Insertion: Proximal olecranon and deep fascia of arm after joining with lateral and long heads
    - Nerve supply: Radial and branches of ulnar nerve
    - Blood supply: Deep brachial artery branches
    - Action: Elbow extension
  - Anconeus muscle
    - Origin: Lateral epicondyle of humerus
    - Insertion: Lateral cortex of olecranon and posterior 1/4 of ulna
    - Nerve supply: Radial nerve
    - Blood supply: Deep brachial artery branch
    - Action: Assists elbow extension, abducts ulna
- **Fascia**
  - Brachial fascia
    - Continuous with fascia covering deltoid and pectoralis major
    - Varies in thickness; thin over biceps and thick over triceps muscles
    - Lateral intermuscular septum from lower aspect of greater tuberosity to lateral epicondyle
    - Medial intermuscular septum from lower aspect of lesser tuberosity to medial epicondyle
    - Perforated by ulnar nerve, superior ulnar collateral artery and posterior branch of inferior ulnar collateral artery
    - Provides traction on deep fascia of forearm
  - Bicipital fascia
    - Also known as lacertus fibrosus
    - Arises from medial side of distal biceps tendon at level of elbow joint
    - Passes superficial to brachial artery
    - Continuous with deep fascia of forearm

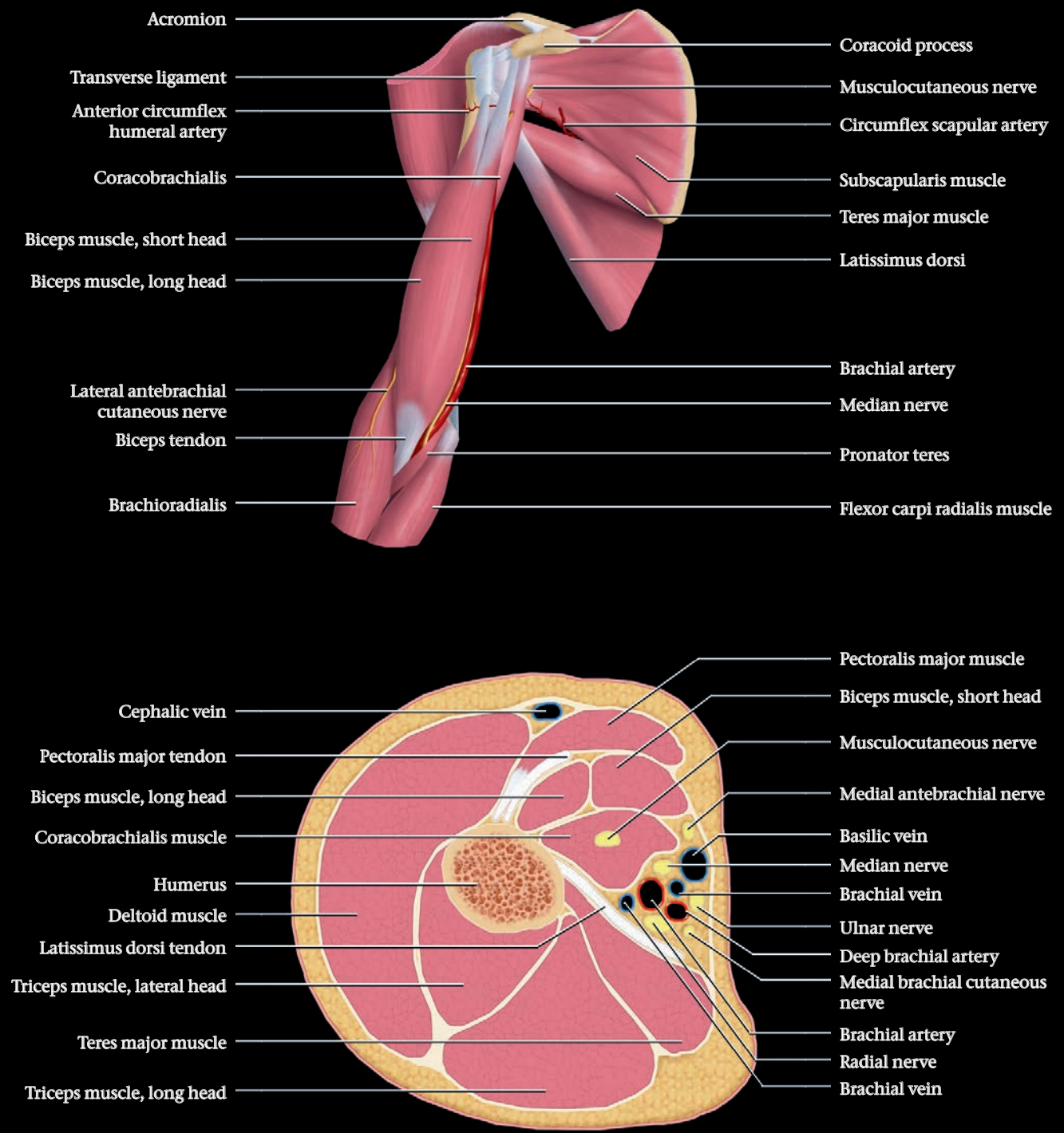
ANATOMY IMAGING ISSUES

Imaging Recommendations

- Examine with arm extended in supine and prone positions
- Transverse plane most helpful to delineate borders of anterior and posterior compartments and relationship to neurovascular structures

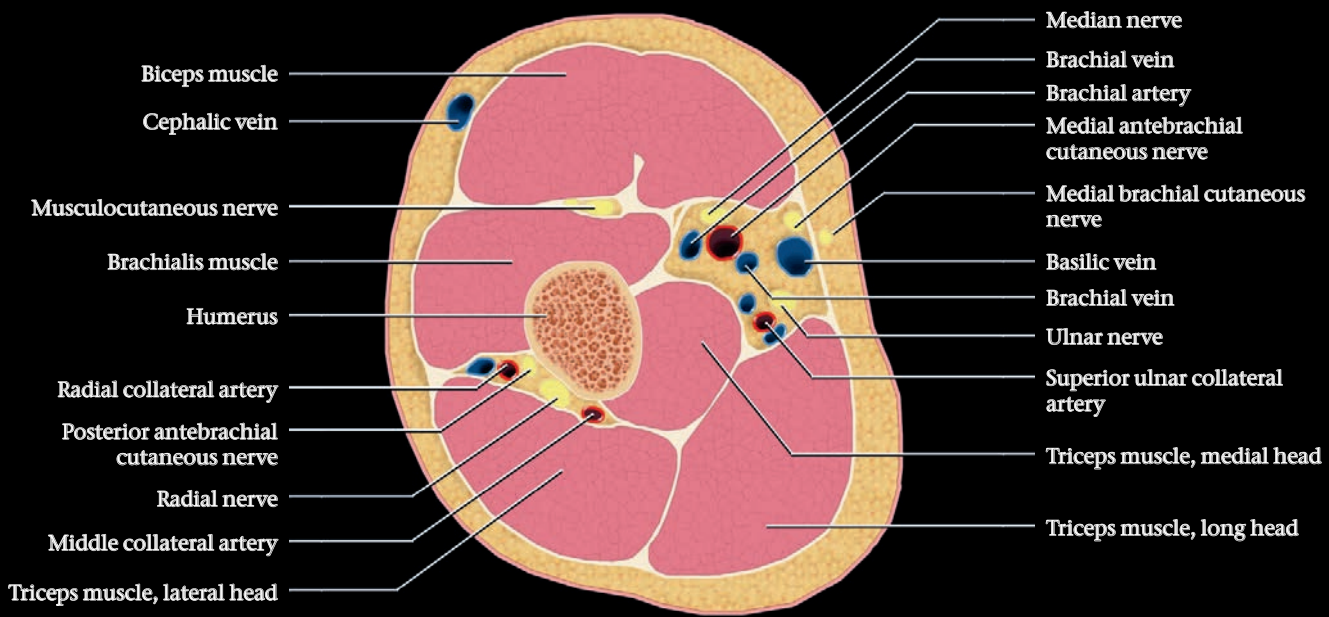
Imaging Pitfalls

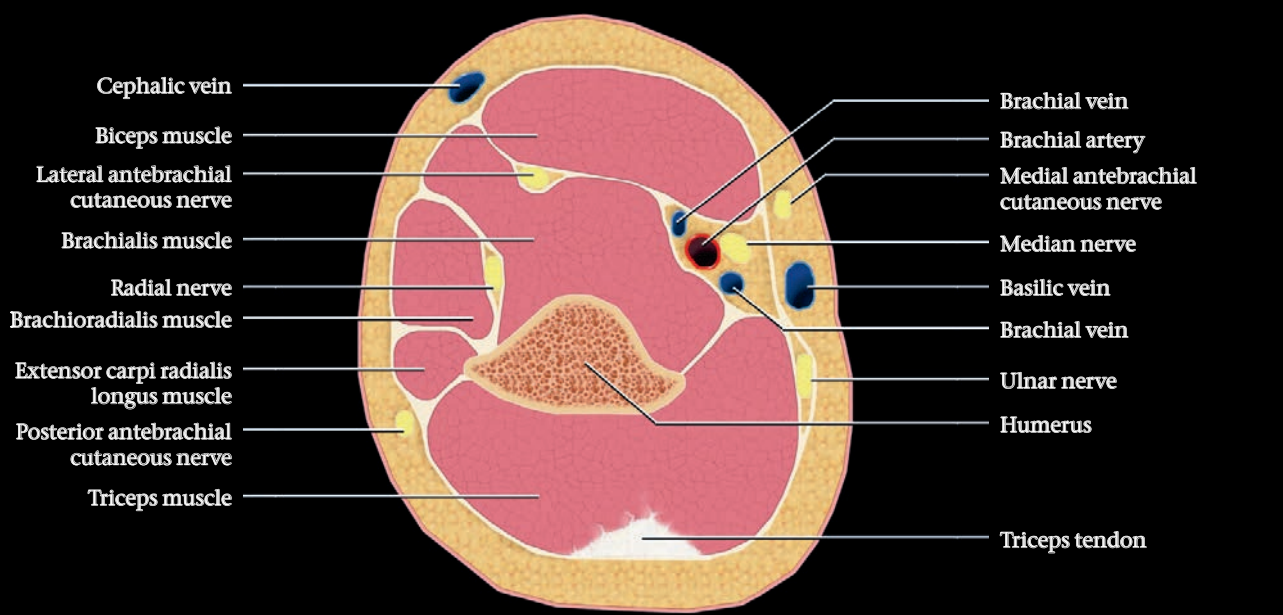
- Muscle may appear echogenic, simulating fatty replacement or edema when beam not aligned parallel to muscle fibers



(Top) *Anterior graphic of the arm is shown. The short head of the biceps originates from the coracoid process tip, in common with the coracobrachialis tendon. The long head of biceps tendon originates from the biceps labral complex at the supraglenoid tubercle and extends along the rotator cuff interval and bicipital groove of humerus to join with the short head and form the biceps muscle. The brachialis muscle originates from distal 1/2 of anterior humeral shaft. The transverse ligament spans the proximal bicipital groove from medial to lateral lip. Anatomical studies suggest that the transverse ligament is formed from fibers of the subscapularis tendon as well as a more superficial discrete fibrous band.* ***(Bottom)*** *Graphic shows the upper humeral level. Note that the coracobrachialis muscle is lying deep to the biceps muscle. In the posterior compartment, the lateral head and long heads of triceps muscles can be seen at this level. All the neurovascular bundles are lying on the medial side of the upper arm.*

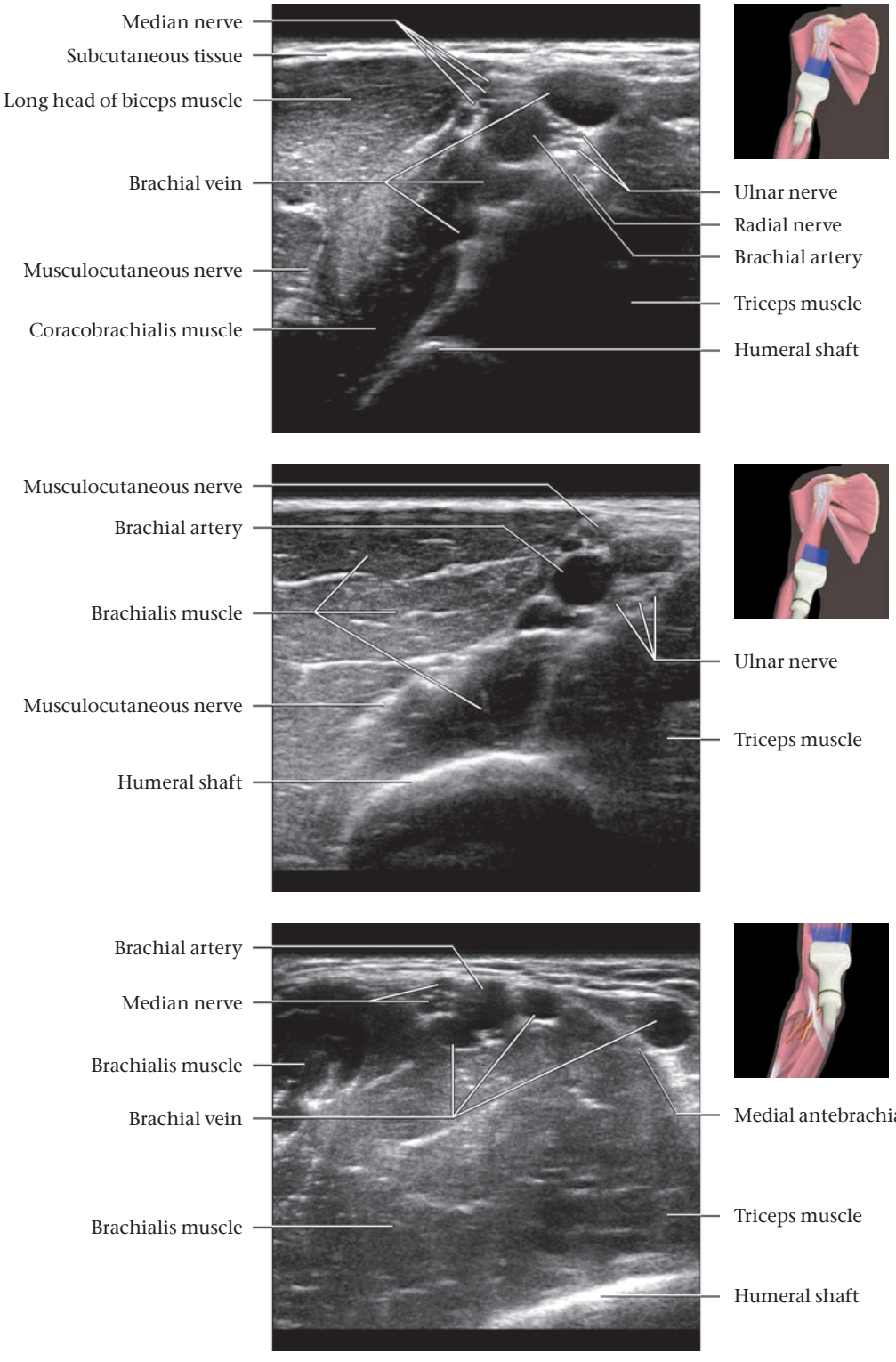
GRAPHICS, ARM





*(**Top**) Axial graphic shows the right arm at the midhumeral level. The posterior compartment of the arm consists of 3 heads of triceps muscle and the medial head of the triceps can be delineated in this level. In the anterior compartment, the brachialis can be delineated at this midarm level. (**Bottom**) Axial section shows the distal humeral level. The deep brachial artery and radial nerve course along the posterolateral humerus reaching the anterolateral aspect of the humerus at this level. The median nerve is lying within the intermuscular septum. The biceps muscle is thinning anteriorly, and the triceps tendon appears.*

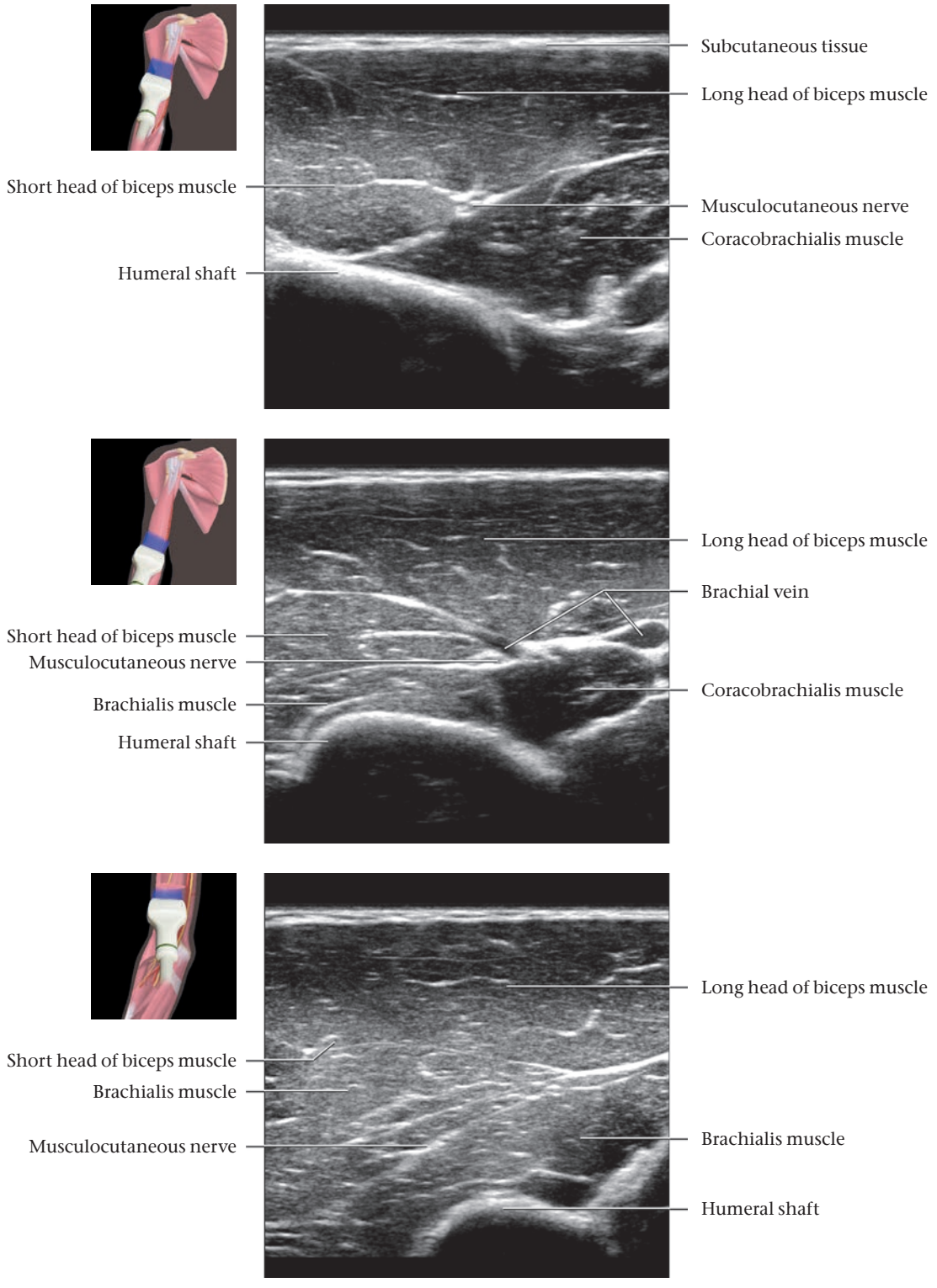
TRANSVERSE US, ANTEROMEDIAL ASPECT



(Top) *Transverse grayscale ultrasound shows the anteromedial aspect of the upper arm. The terminal branches of the brachial plexus (namely, the median nerve, ulnar nerve, and radial nerve) all lie around the brachial vein and artery. They can be recognized by their position relative to the brachial artery, the radial nerve lying deep, median nerve laterally, and ulnar nerve medially.* ***(Middle)*** *Transverse grayscale ultrasound shows the anteromedial aspect of the midarm. Compression of the median or ulnar nerve is uncommon in the midarm. The neurovascular bundle helps define the separation of the anterior and posterior compartments of the arm medially.* ***(Bottom)*** *Transverse grayscale ultrasound shows the anteromedial aspect of the distal arm. In the distal arm, the median nerve alone is closely associated with the brachial neurovascular bundle.*

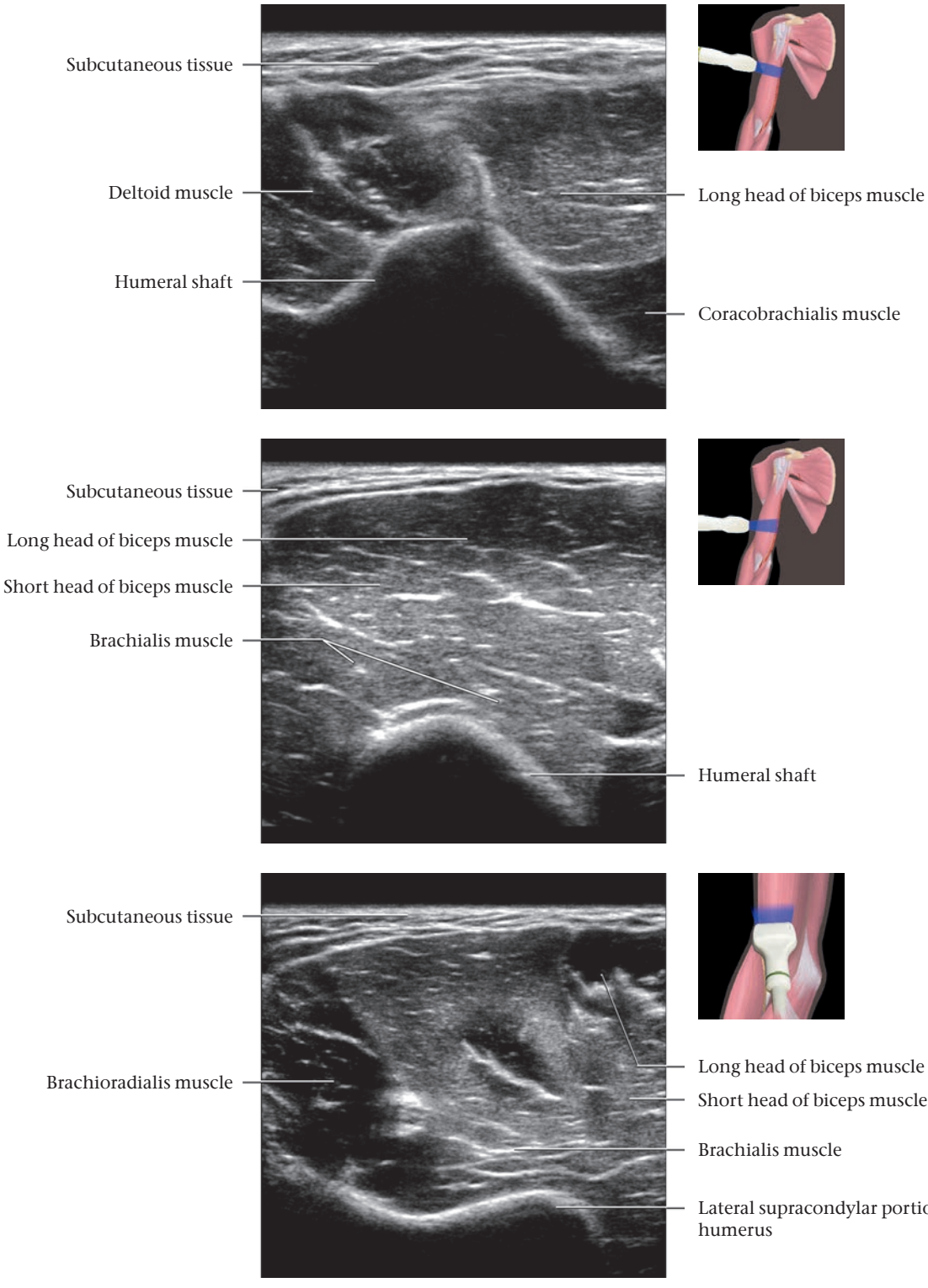
ARM

TRANSVERSE US, ANTERIOR ASPECT



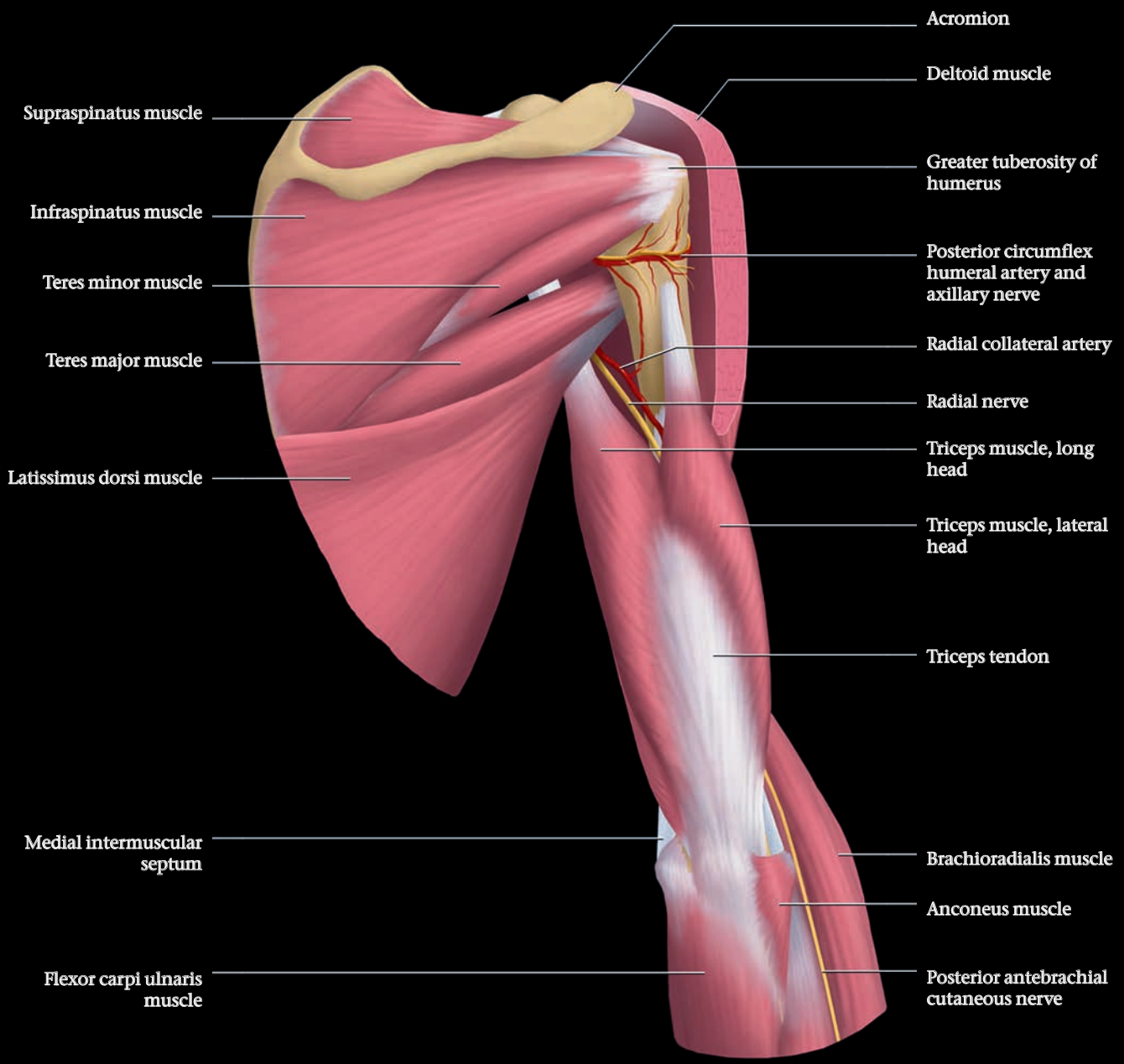
(Top) *Transverse grayscale ultrasound shows the proximal 1/3 of the arm. The anatomy of the upper arm is quite straightforward. The arm muscles are divided into 2 compartments. The anterior compartment is composed of the biceps, brachialis, and coracobrachialis muscles. The biceps muscle is midline, the brachialis muscle is midline and lateral, and the coracobrachialis muscle is midline and medial.* ***(Middle)*** *Transverse grayscale ultrasound shows the mid 1/3 of the anterior arm. Most of the neurovascular bundles in the arm lie anteromedially.* ***(Bottom)*** *Transverse grayscale ultrasound shows the distal 1/3 of the anterior arm. The musculocutaneous nerve is the main critical neurovascular structure of the anterior arm lying between the biceps, coracobrachialis, and brachialis muscles.*

TRANSVERSE US, ANTEROLATERAL ASPECT



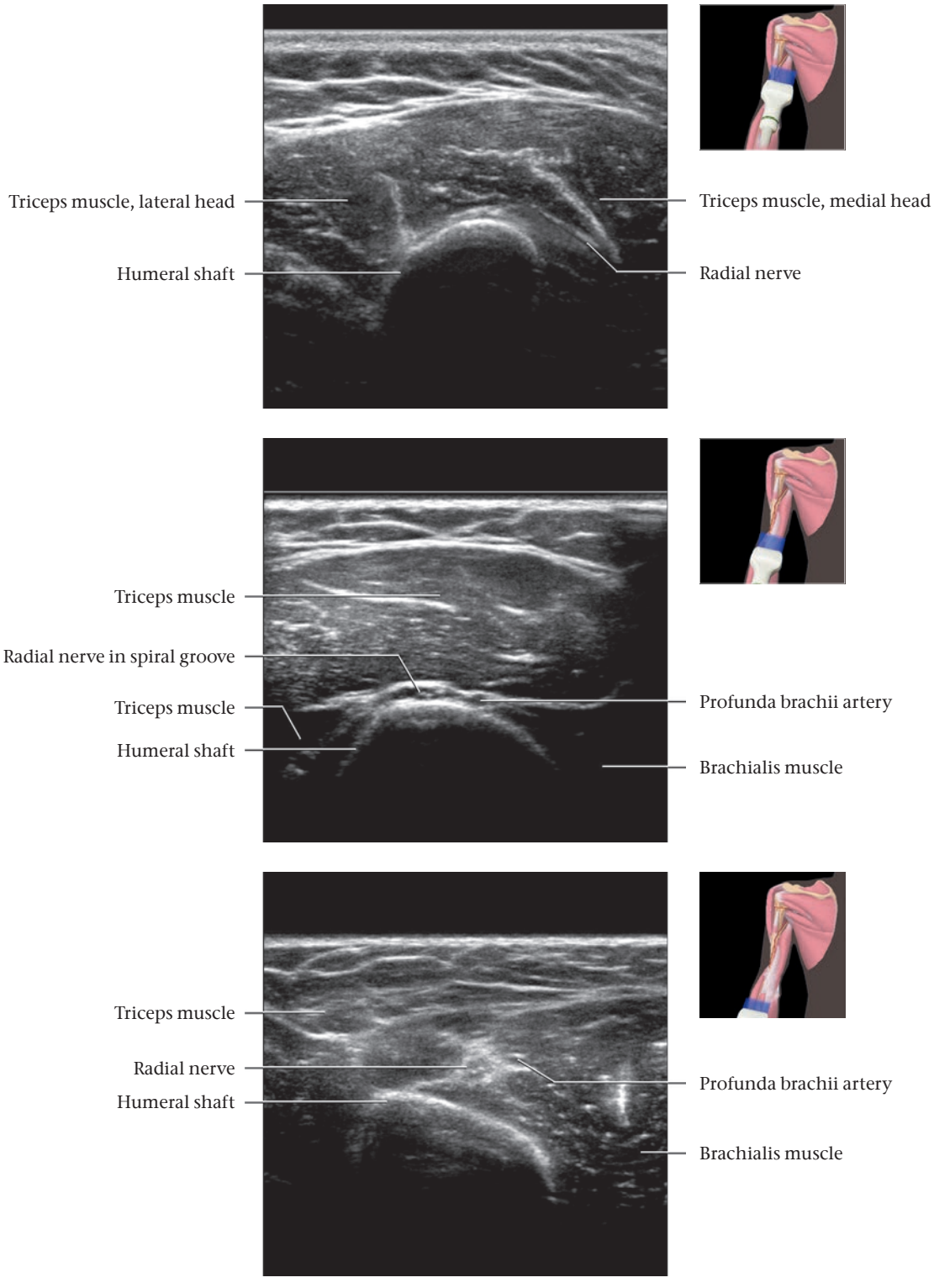
(Top) *Transverse grayscale ultrasound shows the anterolateral aspect of the proximal arm. This is an area prone to injury during contact sports. Fortunately, there is no neurovascular bundle in the area that would be exposed to injury.* ***(Middle)*** *Transverse grayscale ultrasound shows the anterolateral section of the midarm. Both the biceps muscle and brachialis muscle may be prone to overuse muscle injury if too vigorous exercise is undertaken. The biceps muscle may appear echogenic if the transducer is aligned at an angle to the transverse plane.* ***(Bottom)*** *Transverse grayscale ultrasound shows the anterolateral aspect of the distal arm. Both heads of the biceps converge to form the distal biceps tendon just proximal to the antecubital fossa.*

GRAPHIC, POSTERIOR ARM



Graphic shows the superficial dissection of the posterior arm. Note that the quadrilateral space is an anatomic space bounded by the long head of the triceps, teres minor and teres major muscles, and cortex of humerus. Axillary nerve and posterior circumflex humeral artery are within the space. Any narrowing of this space will cause quadrilateral space syndrome.

TRANSVERSE US, POSTERIOR ASPECT



(Top) *Transverse grayscale ultrasound shows the posterior upper arm. The triceps muscle occupies nearly the whole of the posterior upper arm. The radial nerve supplies the triceps and supinator muscles.* ***(Middle)*** *Transverse grayscale ultrasound shows the posterior midarm. The radial nerve runs in the spiral groove on the posterior aspect of the midarm. At this level, it is prone to injury from humeral shaft fractures, fibrosis, or fibrotic bands following trauma or extrinsic compression.* ***(Bottom)*** *Transverse grayscale ultrasound shows the posterior aspect of the distal arm. The radial nerve pierces the lateral intermuscular septum just proximal to the lateral epicondyle. It then runs between the brachialis and brachioradialis muscles and passes anterior to the lateral epicondyle. The nerve may be compressed by the lateral intermuscular septum.*

ARM VESSELS

GROSS ANATOMY

Arteries

- Brachial artery
- Continuation of axillary artery
- Extends from lower border of teres major to neck of radius
- Accompanies median nerve
- Branches of brachial artery in arm
  - Superior ulnar collateral arises medially, descends with ulnar nerve posterior to medial epicondyle, and then forms anastomosis with branches of ulnar artery
  - Inferior ulnar collateral arises distal to superior ulnar collateral artery, descends anterior to medial epicondyle, and then forms anastomosis with branches of ulnar artery
  - Profunda brachii: Main branch of brachial artery
    - Arises just distal to teres major, accompanies radial nerve, and passes backwards in spiral groove on posterior surface of humerus
    - Gives off another branch, which passes upwards and anastomoses with arteries around shoulder joint
    - Gives 2 lower medial branches, which descend to elbow joint on its medial side and take part in anterior and posterior anastomosis around elbow joint
- Brachial artery lies superficial in its course in arm
- Covered by bicipital aponeurosis at elbow where it may be compressed against medial surface of humerus
- Brachial artery divides at neck of radius into radial artery and ulnar artery
  - High takeoff of radial artery from brachial artery is a common anatomical variant
  - Radial artery passes inferiorly and laterally, lying on tendon of biceps brachii
  - Ulnar artery passes down and medially, deep to pronator teres
  - Within antecubital fossa, radial and ulnar arteries give off recurrent branches to elbow joint

Veins

- Categorized as superficial and deep venous system
  - Veins of upper limb are variable in number and position
- Brachial vein
  - Forms deep venous system
  - Singular or paired, continue into axillary vein
  - Accompanied by brachial artery and nerves of upper limb
- Cephalic vein
  - Lies anterolaterally in superficial fascia of antecubital fossa and gives off medial cubital vein, which joins basilic vein
  - Runs in deltopectoral groove before piercing clavipectoral fascia to drain into axillary vein
- Basilic vein
  - Passes upwards on medial side of forearm, receiving anterior and posterior tributaries, and then passes to anteromedial aspect of elbow where it receives medial cubital vein
  - Continues on medial aspect of biceps brachii until it pierces deep fascia to run cranially, medial to brachial artery
  - Joins brachial vein and becomes axillary vein at lower border of teres major

ANATOMY IMAGING ISSUES

Imaging Recommendations

- Venous examination
  - Examination of upper limb veins is normally performed with patient supine and arm abducted to about 90°
  - Use of high-frequency linear transducer (5-10 MHz) is recommended
    - Determination of compressibility
    - Flow pattern: Normal venous waveform
  - Augmentation of flow is obtained by manual compression of forearm or upper arm
    - Alternatively, patient clenches fist to increase venous flow
    - Flow can also be augmented by deep inspiration
- Arterial examination
  - In patients with possible arterial compression syndromes, arteries are examined in various positions of shoulder abduction so that any compression may be accentuated

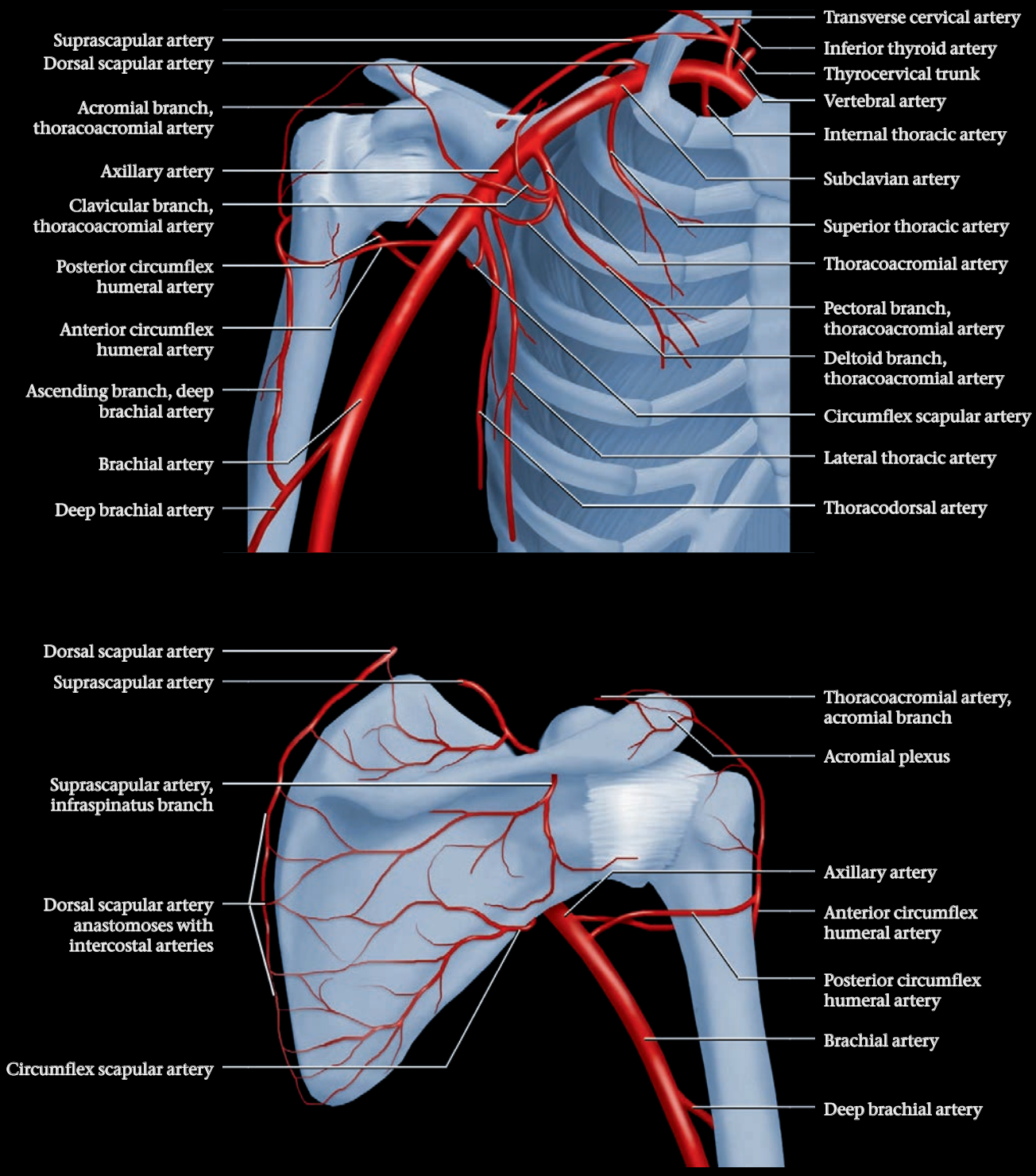
Imaging Pitfalls

- Clavicle can produce mirror artifact of subclavian vessels
- Brachial vein duplication is common
- Due to proximity, arm venous flow is affected by respiration
  - Deep inspiration will augment flow
- Angle of insonation should not be > 60° as this will reduce sensitivity of Doppler and color flow signals
- Color signal scale should match flow velocity
- Doppler gate should be located at center of artery or vein as this is the site of peak flow velocity
- Arteriography: Gold standard for assessment of accuracy of arterial Doppler ultrasound with respect to stenoses or occlusion
  - Other methods of visualizing arterial tree are computed tomography angiography and magnetic resonance angiography

CLINICAL IMPLICATIONS

Clinical Importance

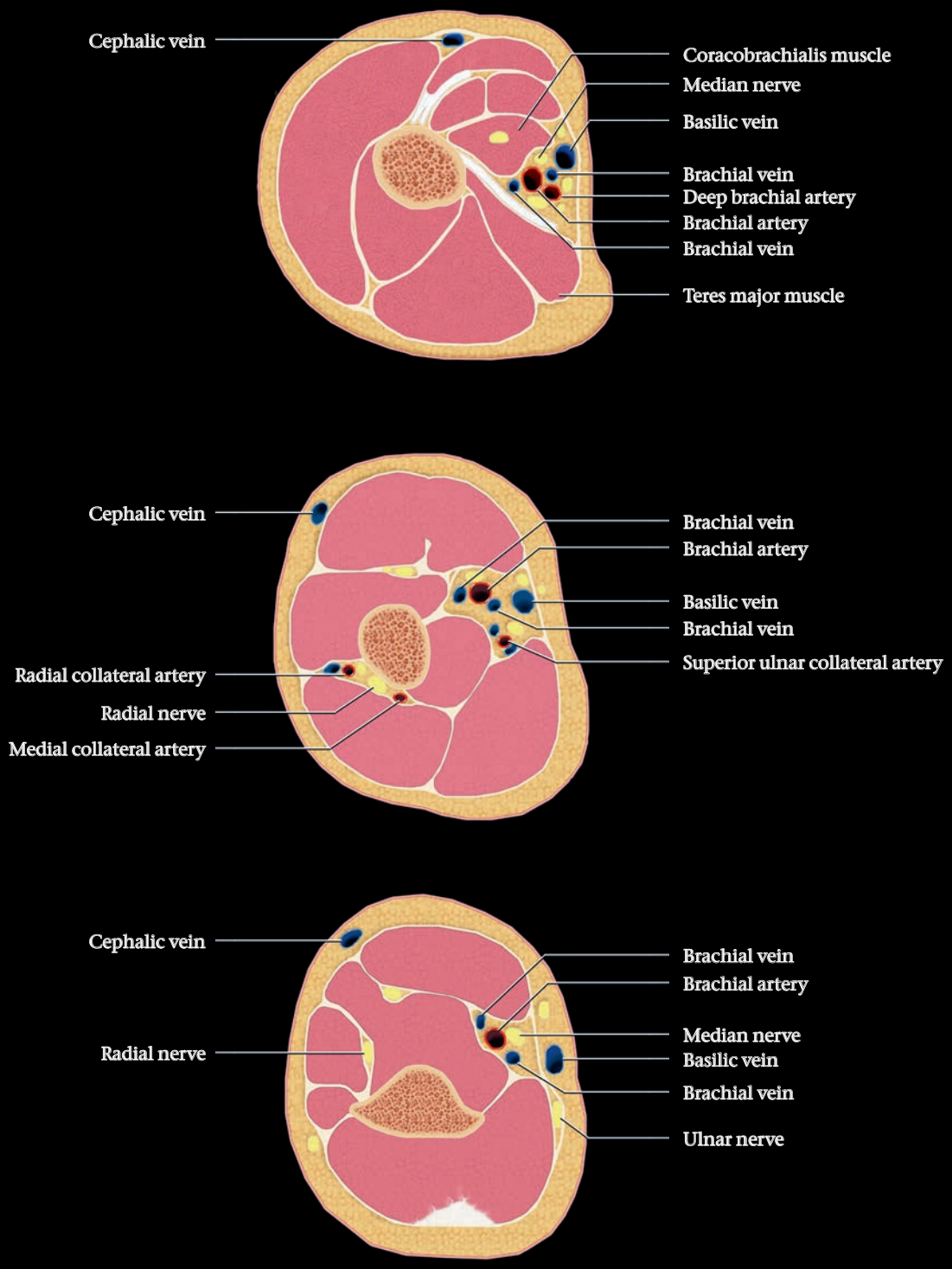
- Brachial artery may be used for access in angiography, either by a high brachial approach or in antecubital fossa, where it lies medial to biceps tendon and lateral to median nerve
- Spontaneous thrombosis of axillary vein occasionally occurs following excessive movements of arm at shoulder joint
- Diagnosis of exclusion of deep vein thrombosis in upper or lower limb; spontaneous or related to indwelling catheters
- Vein mapping prior to bypass grafts
- Localization of veins for venous access and cannulation



(Top) *Anterior graphic shows arterial supply to the shoulder. The shoulder is predominantly supplied by the anterior and posterior circumflex humeral, suprascapular, and circumflex scapular arteries.* ***(Bottom)*** *Posterior graphic shows arterial supply to the shoulder. Extensive collateral blood vessels include anastomoses with intercostal arteries.*

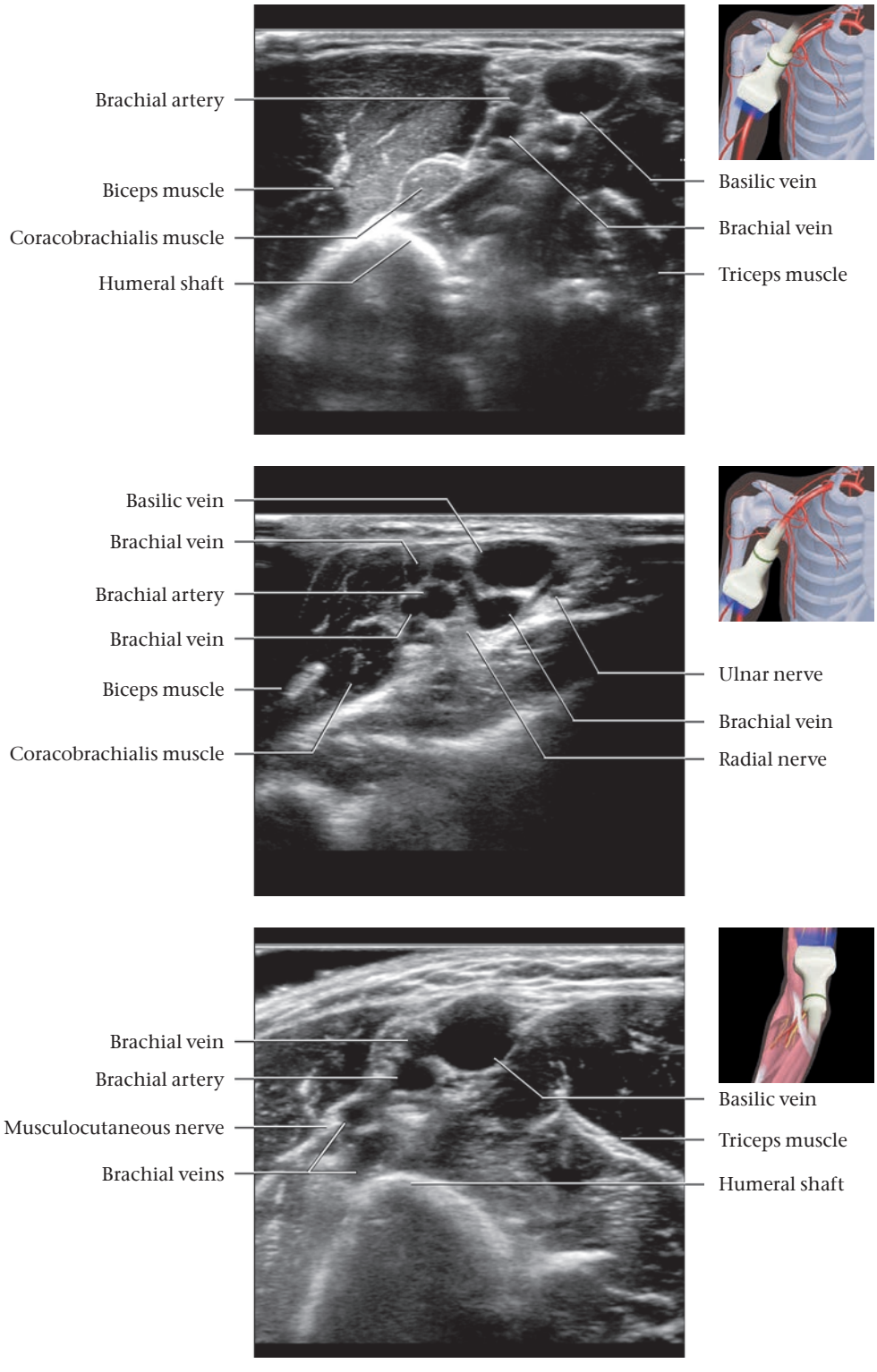
ARM VESSELS

AXIAL GRAPHICS, RIGHT ARM



(Top) *Axial graphic shows the upper right arm. The brachial artery is a continuation of the axillary artery and accompanies the median nerve. The deep brachial artery (profunda brachii artery) is the main branch of brachial artery and accompanies the radial nerve. The basilic vein lies medially and the cephalic vein anterolaterally.* ***(Middle)*** *Axial graphic shows the right arm at the midhumeral level. Note that the profunda brachii artery accompanies the radial nerve and passes backwards in spiral groove of humeral shaft before dividing into medial and radial collateral arteries. Superior ulnar collateral artery arises from the brachial artery and descends with the ulnar nerve.* ***(Bottom)*** *Axial graphic shows the right arm at the distal humeral level. Note how the median nerve is on the medial side of the brachial artery at this level.*

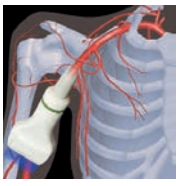
TRANSVERSE US, PROXIMAL ARM

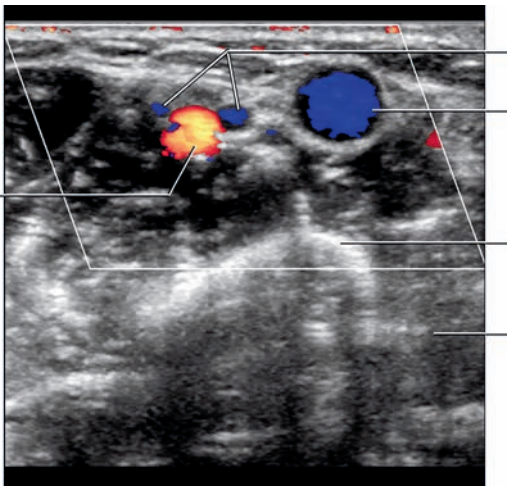


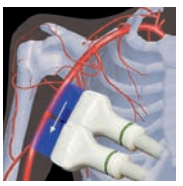
(Top) *Transverse grayscale ultrasound shows the vessels of the proximal arm. The basilic vein lies deep to the investing fascia in the arm. The veins are highly variable in location and are surrounded by nerves; hence, ultrasound guidance is helpful when cannulating the veins of the arm.* ***(Middle)*** *Transverse grayscale ultrasound shows the vessels of the midarm. The basilic vein is formed on the ulnar side of the wrist and is joined by the median cubital vein (from cephalic vein at the elbow). In some cases, the brachial artery may bifurcate in the midarm or higher.* ***(Bottom)*** *Transverse grayscale ultrasound shows the vessels of the distal arm. The brachial artery can be seen clinically as a pulsatile vessel in "locomotor brachialis," i.e., in arteriosclerosis.*

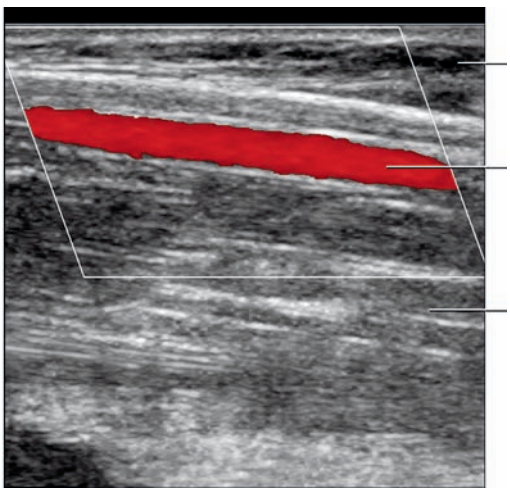
ARM VESSELS

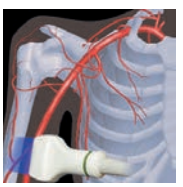
COLOR DOPPLER, BRACHIAL ARTERY







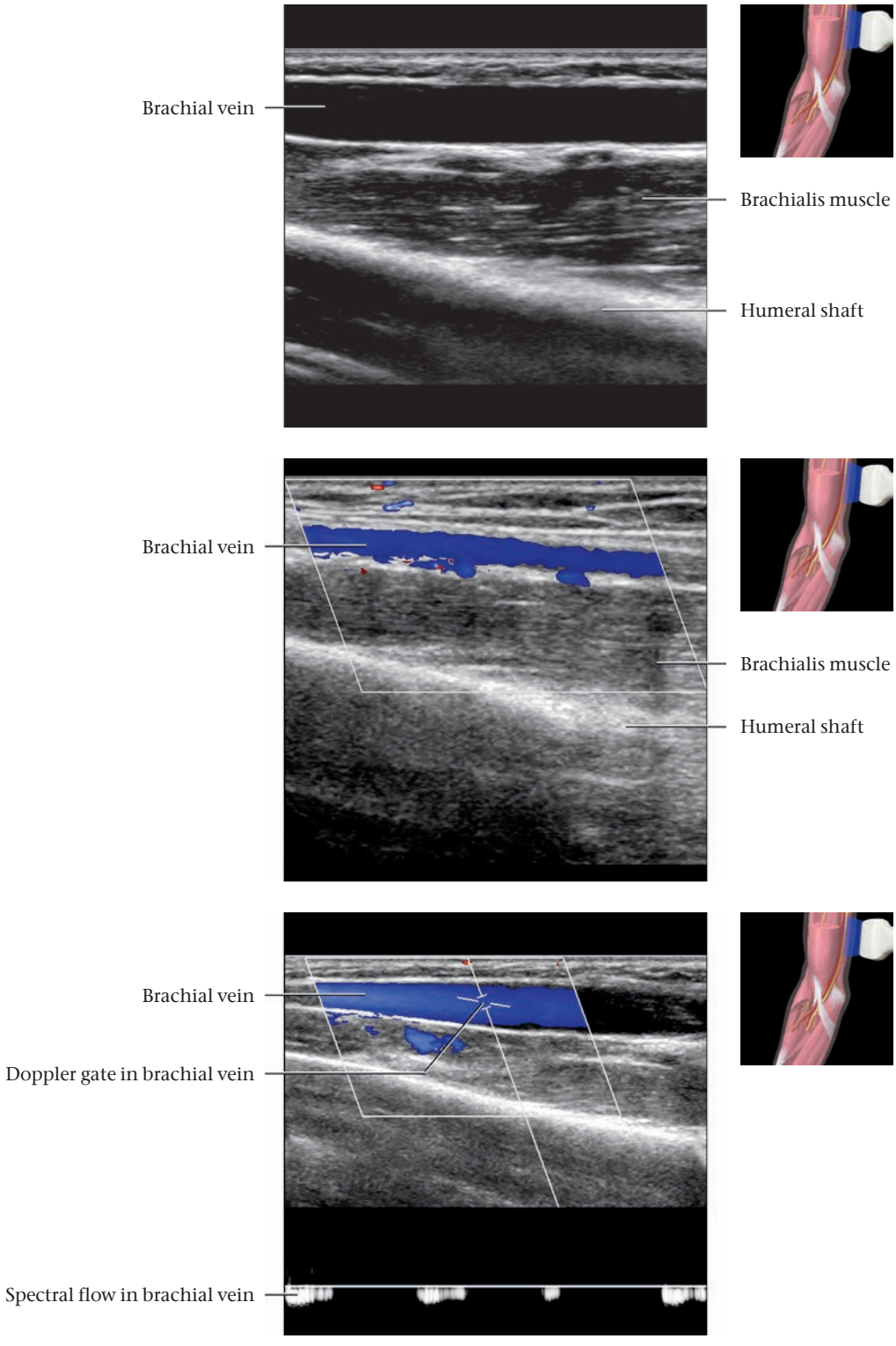






(Top) *Transverse color Doppler ultrasound shows the brachial artery. Note the accompanying paired brachial veins.* ***(Middle)*** *Longitudinal color Doppler ultrasound shows the brachial artery. The normal diameter of the brachial artery at the antecubital fossa ranges from 5.5-6 mm.* ***(Bottom)*** *Longitudinal color Doppler spectral analysis ultrasound shows the brachial artery. Normal triphasic flow pattern of the large arteries is seen, compared to the biphasic flow of more distal arteries, but changes in temperature or even maneuvers such as fist clenching may dramatically change the characteristics of upper extremity waveforms, especially in and near the hands. Peak systolic velocity of the brachial artery ranges from 50-100 cm/s (average 57 cm/s); end diastolic velocity (EDV) 7-12 cm/s and a pulsatility index (PI) around 5 is considered normal.*

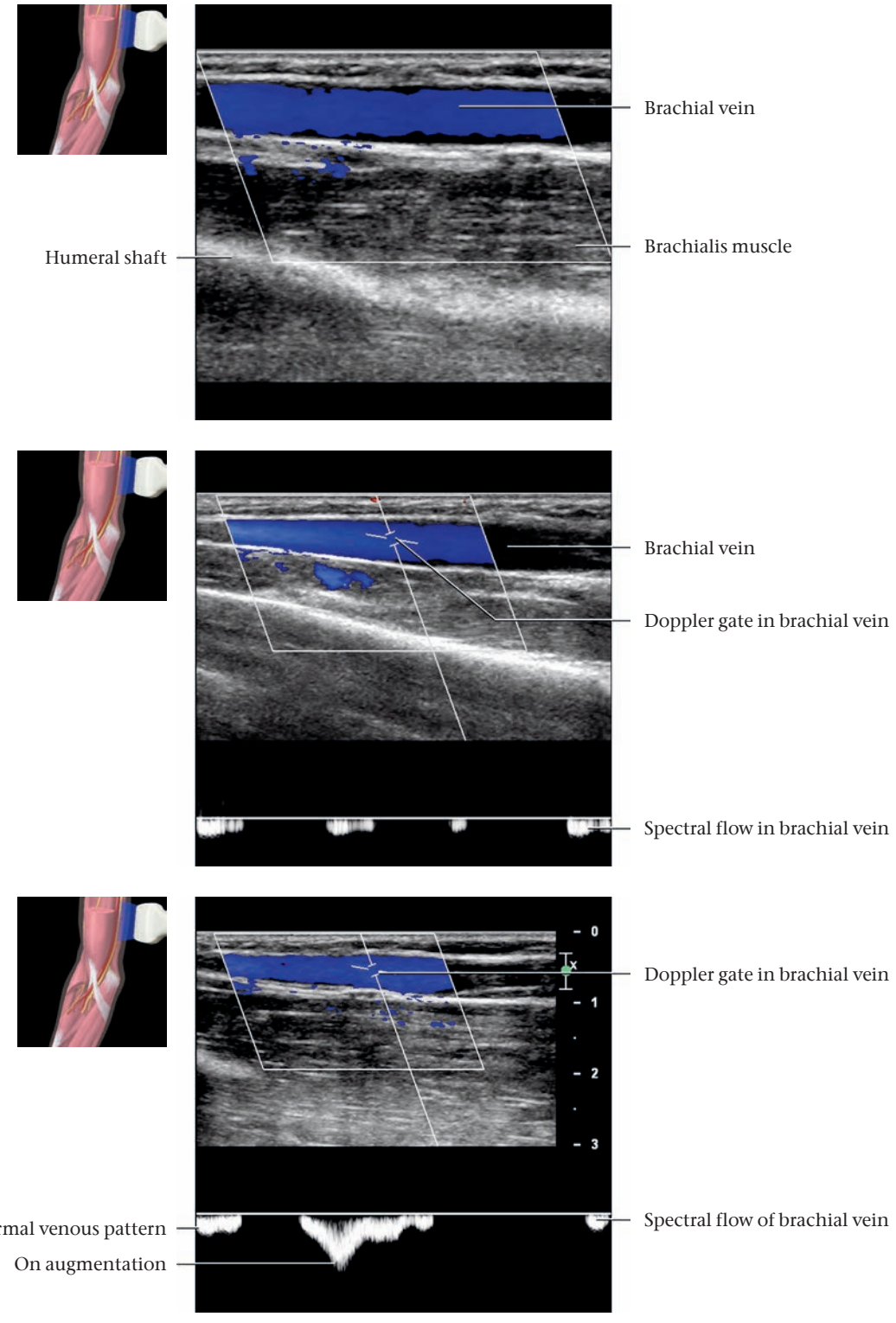
LONGITUDINAL COLOR DOPPLER, BRACHIAL VEIN



(Top) *Longitudinal grayscale ultrasound shows the brachial vein. Normal brachial vein in the upper arm measures around 2.5-2.7 mm. The venous system of the upper limb is categorized as a superficial and deep system. Brachial vein constitutes the deep venous system. Brachial veins can be paired or singular.* ***(Middle)*** *Longitudinal color Doppler ultrasound shows the brachial vein. The ulnar and radial veins collect blood from the deep palmar arch and run in pairs alongside the corresponding arteries. They unite slightly above the elbow joint and flow into the brachial veins, which may be either paired or singular.* ***(Bottom)*** *Spectral Doppler ultrasound shows the flow pattern in the brachial vein. The flow is intermittent due to respiration. Examinations using proximal compression are not clinically relevant. Distal compression, which produces augmentation sounds, helps locate the veins.*

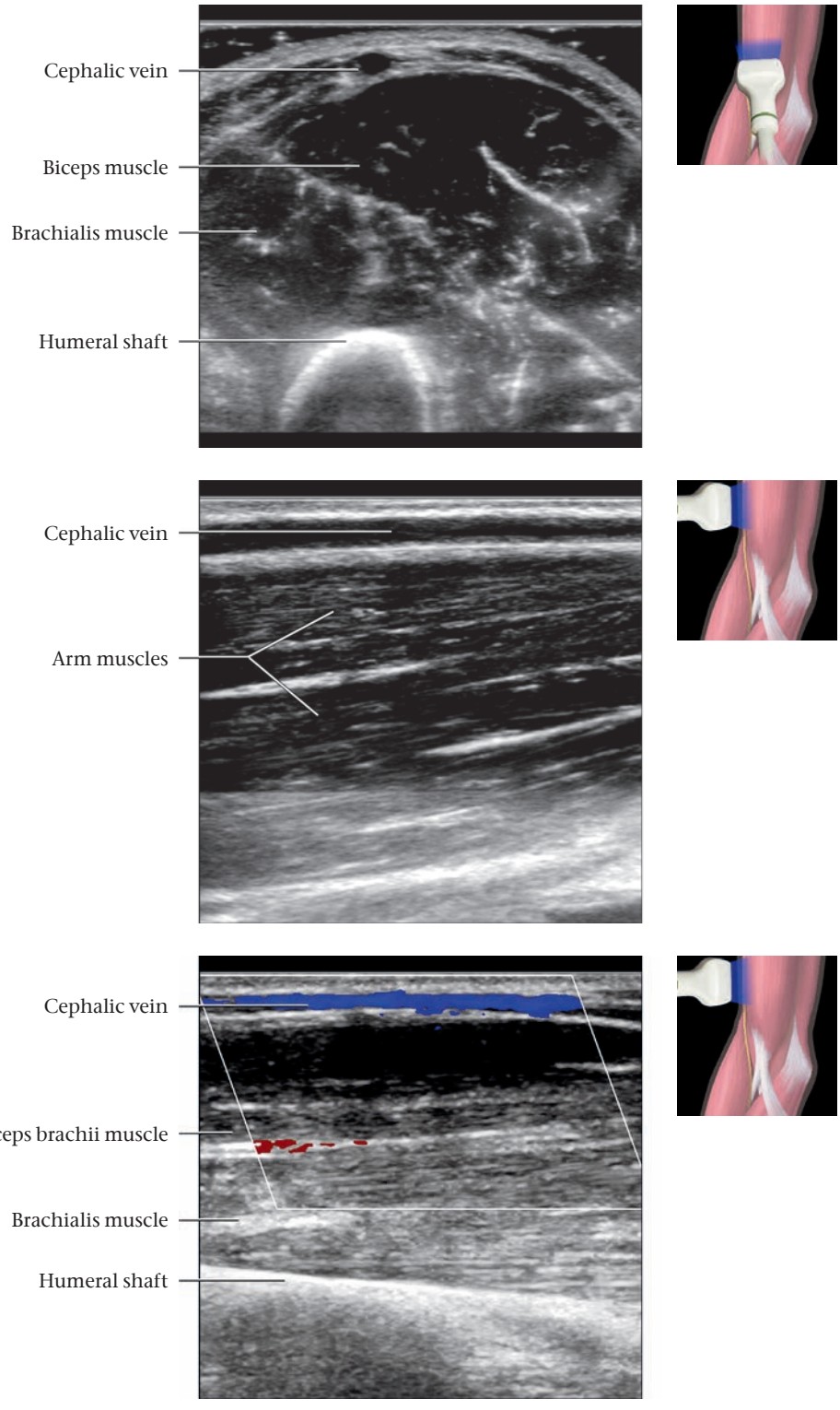
ARM VESSELS

LONGITUDINAL US, DYNAMIC



(Top) *Longitudinal color Doppler ultrasound shows the brachial vein. Using Doppler mode, phasic flow during normal respiration is observed.* ***(Middle)*** *Spectral Doppler ultrasound shows the flow pattern in the brachial vein. In the upper extremities, including the subclavian vein, the behavior of venous flow during respiration is the opposite of what it is in the lower body region. During inspiration, pressure in the thorax decreases, and the venous blood flows toward the heart. During expiration, the thoracic pressure increases and the flow decreases or even ceases during deep respiration.* ***(Bottom)*** *Spectral Doppler ultrasound shows the phenomenon of augmentation, demonstrating the patency of the veins. It involves squeezing of the distal arm muscles (causing motion artifacts from movement), which will increase venous flow. Deep inspiration will have the same effect.*

TRANSVERSE AND LONGITUDINAL US, CEPHALIC VEIN



(Top) *Transverse grayscale ultrasound at the proximal arm shows the cephalic vein. The normal diameter of the cephalic vein just above the elbow measures 2.5-2.9 mm.* ***(Middle)*** *Longitudinal grayscale ultrasound at the proximal arm shows the cephalic vein. The most important veins of the arm are the cephalic vein and basilic veins. The superficial cephalic vein unites the deep-seated brachial and axillary veins. Assessment of valvular insufficiency has no clinical role in the upper limb vessels.* ***(Bottom)*** *Longitudinal color Doppler ultrasound in the distal arm shows the cephalic vein. Color flow duplex sonography allows ready assessment of the important upper arm veins (the paired brachial veins, cephalic veins, and basilic veins). Continuous color intensity makes it possible to exclude thromboses.*

ELBOW

GROSS ANATOMY

Joint Capsule Attachments

- Posterior
  - Proximally attaches to humerus proximal to olecranon fossa and capitellum; distally attaches to proximal ulna
- Anterior
  - Proximally attaches to humerus proximal to coronoid and radial fossae; distally attaches to coronoid process and annular ligament
- Anterior and posterior elbow fat pads are intracapsular but extrasynovial
- Capsule of elbow is weakest anteriorly; it is strengthened on both sides by ligaments
- Synovial recesses
  - Olecranon recesses
    - Largest; superior, medial, and lateral around olecranon process
  - Anterior humeral recess
    - Proximal to coronoid fossa
  - Annular recess
    - Surrounds radial neck
  - Ulnar collateral ligament recess
    - Deep to ligament
  - Radial collateral ligament recess
    - Deep to ligament
  - Capsule of elbow is weakest anteriorly
    - Capsule is strengthened on both sides by collateral ligaments

Ligaments

- **Ulnar collateral ligament**
  - Extends from distal aspect of medial epicondyle to coronoid and olecranon portions of ulna
  - Separated from overlying common flexor tendon by thin layer of fat
  - 3 bands: Anterior, posterior, and transverse
    - Anterior band: Most important; cord-like, 4-6 mm thick, taut in extension, extends from medial epicondyle to coronoid process (sublime tubercle); divided into superficial and deep layers
    - Posterior band: Less important; fan-like and thinner, taut in flexion, extends from medial epicondyle to olecranon
    - Transverse band: Functionally unimportant; forms base of triangle between anterior and posterior bands
- **Radial collateral ligament**
  - Triangular in shape
  - Apex on lateral epicondyle → blends distally with annular ligament
  - Lies deep to common extensor tendon
  - Provides origin for superficial head of supinator muscle
- **Annular ligament**
  - Attached to anterior and posterior aspects of radial notch of ulna forming a collar around radial head
    - Anterior attachment becomes taut in supination
    - Posterior attachment becomes taut in extreme pronation
    - Provides origin for superficial head of supinator muscle

Tendons

- **Triceps tendon**
  - 3 heads combine to insert onto olecranon process
  - Medial fibers insert exactly on medial margin of olecranon
  - Lateral fibers may fan out as lateral cubital retinaculum to connect with ulna and antebrachial fascia
- **Biceps tendon**
  - Flat tendon forms ~ 7 cm proximal to elbow joint
  - Twists 90° as it passes deep so that anterior surface faces laterally
    - Expands close to attachment into radial tuberosity; attachment area is ~ 3 cm^2
  - Short and long heads have separate adjoined attachments
  - Also attaches to bicipital aponeurosis
    - Bicipital aponeurosis completely encircles ulnar forearm flexor muscles
    - Merges with investing fascia of forearm
    - May be important in stabilizing distal aspect of biceps tendon
- **Common extensor tendon**
  - Arises from lateral epicondyle
  - Superficial to radial collateral ligament
  - Composed of extensor-supinator group
    - Extensor carpi radialis brevis, extensor carpi radialis longus, extensor digiti minimi, extensor digitorum communis
- **Common flexor tendon**
  - Arises from medial epicondyle
  - Superficial to ulnar collateral ligament
  - Composed of flexor-pronator group
    - Flexor carpi radialis, flexor carpi ulnaris, flexor digitorum superficialis, pronator teres, palmaris longus

Bursae

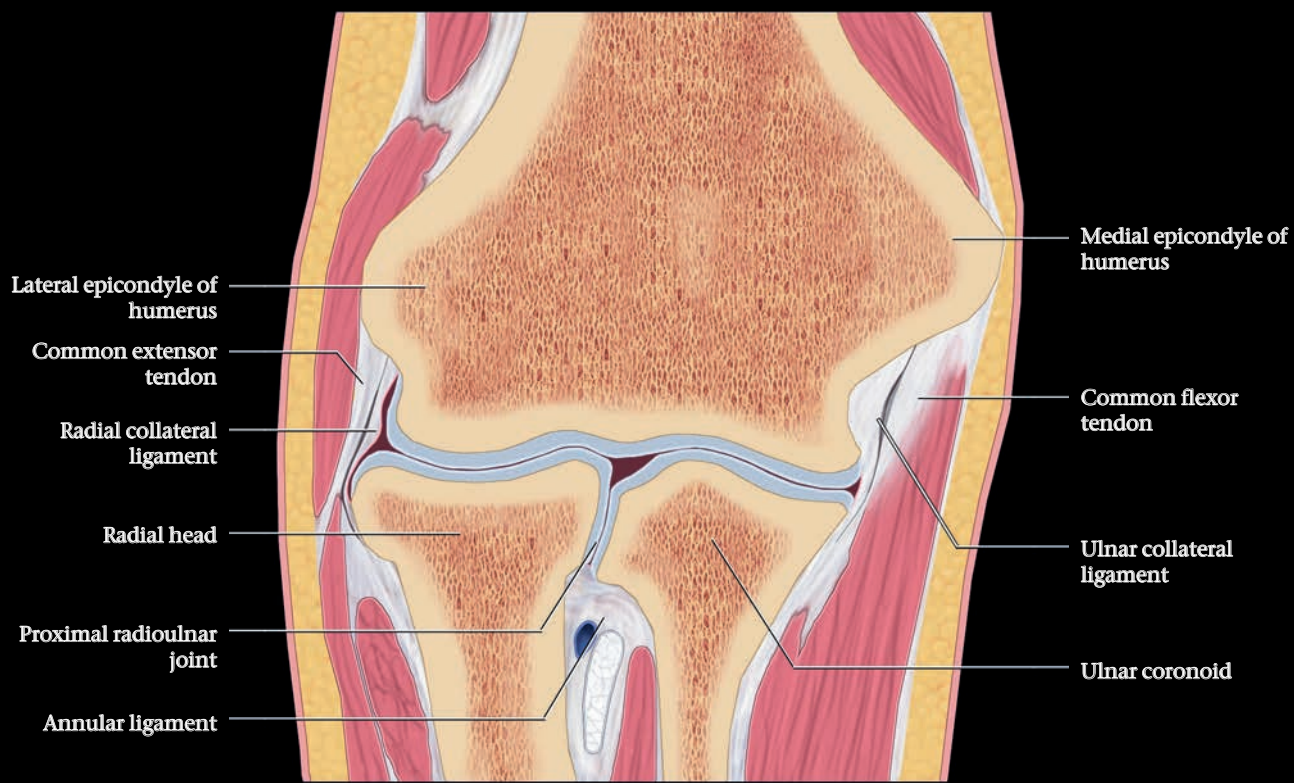
- **Subtendinous olecranon bursa**
  - Between triceps tendon and olecranon
- **Subcutaneous olecranon bursa**
  - Between skin and olecranon process
- **Bicipitoradial bursa**
  - Between biceps tendon and radial tuberosity
- **Radioulnar bursa**
  - Between extensor digitorum and radiohumeral joint

ANATOMY IMAGING ISSUES

Imaging Recommendations

- High-frequency linear transducer
- Large amount of gel for superficial structures
- Examination is usually tailored to site of symptoms
- Lateral elbow is best seen with elbow fully or slightly flexed
- Medial elbow is best seen with elbow extended
- Distal biceps tendon is best seen with forearm in full supination
- Distal biceps tendon insertion is best seen from posterior part of elbow with forearm fully pronated and elbow flexed with transducer aligned transversely over radial tuberosity
- Effusion will displace fat pads away from bone

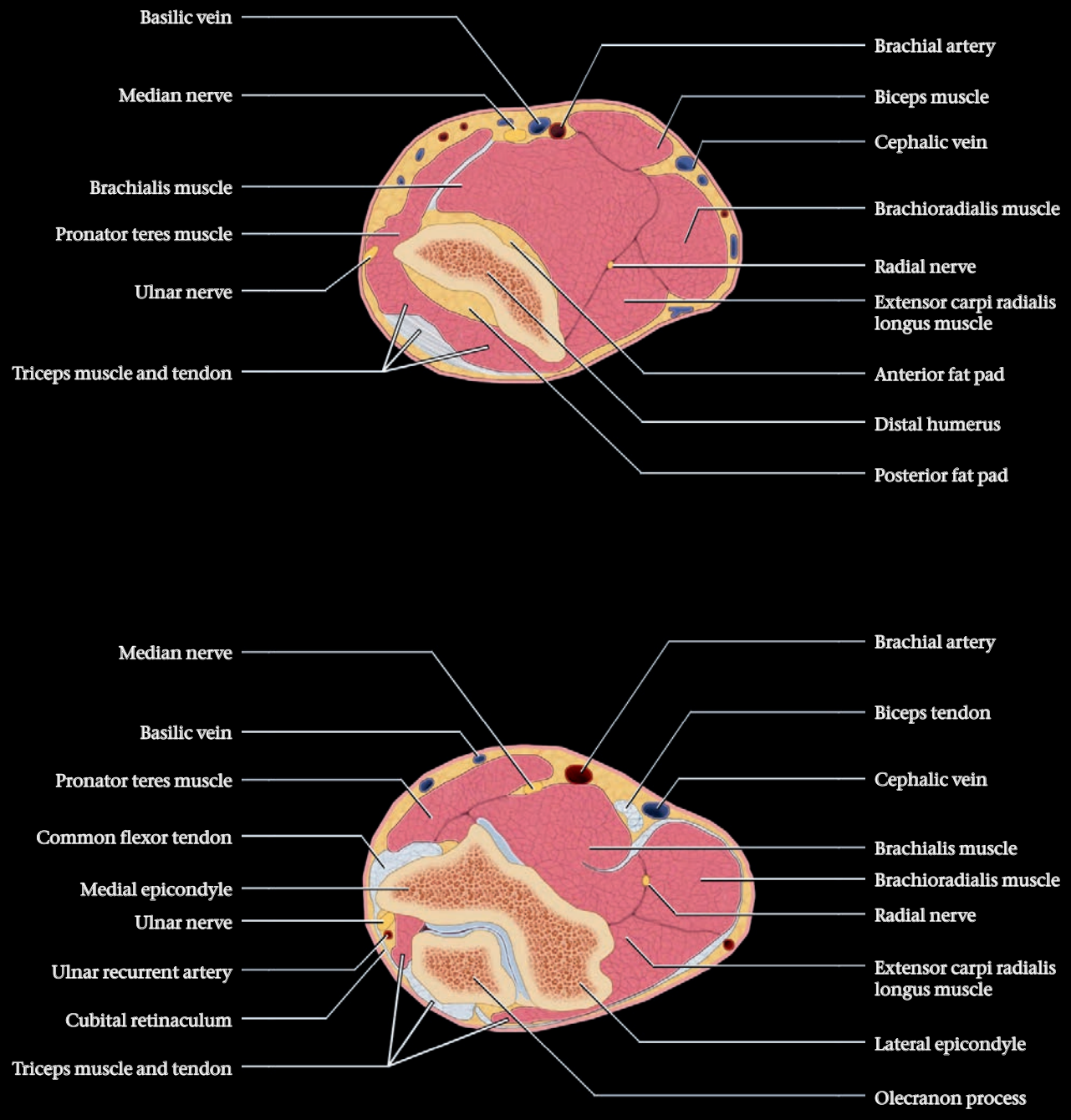
GRAPHIC, CORONAL ELBOW



Coronal section through the level of the epicondyles shows the collateral ligaments deep to the common tendon groups. Although the radial collateral ligament is shown, the section is too anterior to show most of the ulnar collateral ligament, which originates just posterior to the radial collateral ligament.

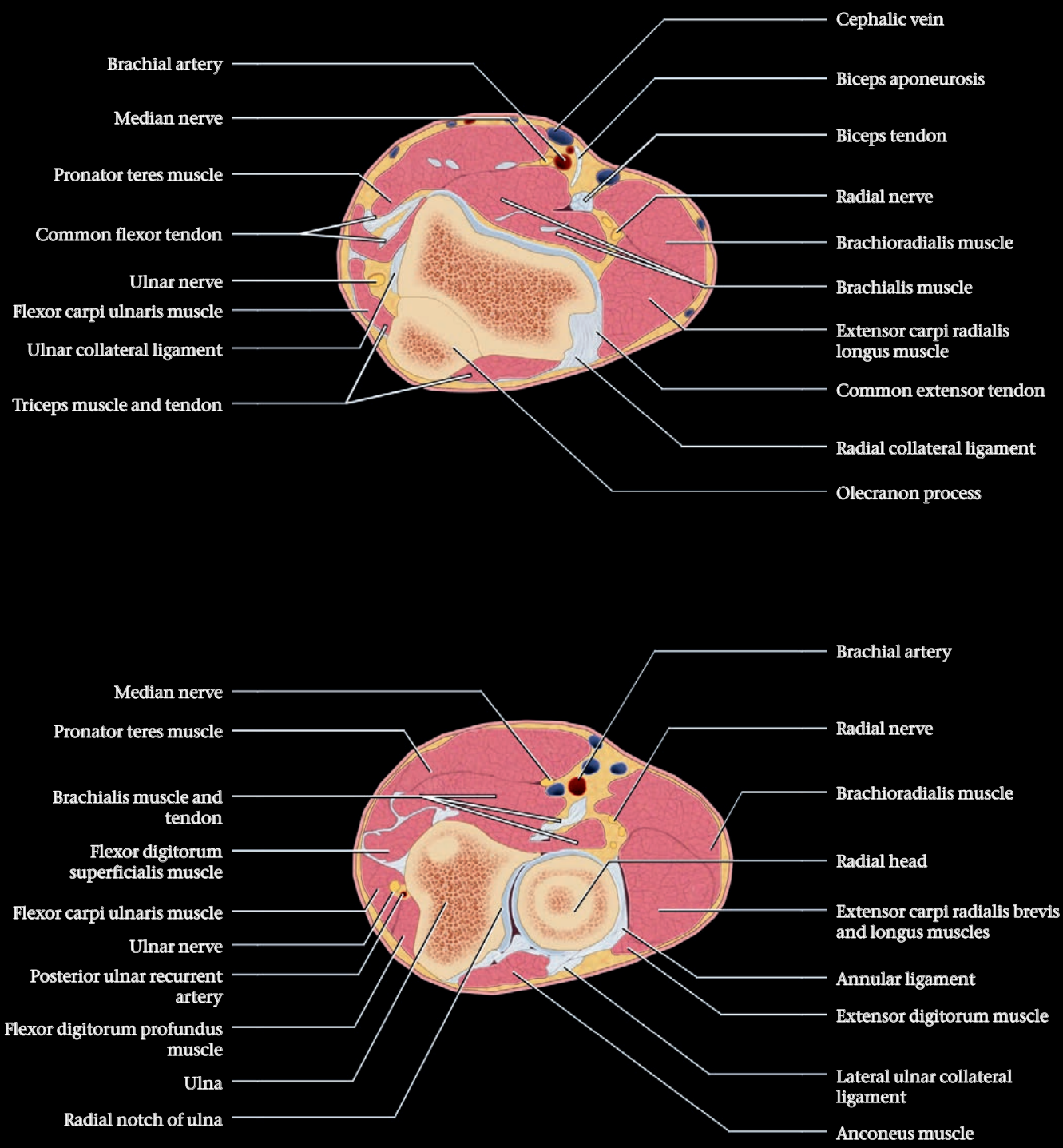
ELBOW

GRAPHICS, PROXIMAL ELBOW CROSS SECTION



*(**Top**) Axial graphic shows the supracondylar region of the humerus. The anterior and posterior fat pads are seen in the coronoid and olecranon fossae, respectively. The brachialis muscle accounts for the bulk of the anterior compartment of the distal arm. (**Bottom**) Axial graphic shows the epicondylar region of the distal humerus. The triceps muscle thins as its tendon attaches to the olecranon. The ulnar nerve and posterior ulnar recurrent artery are held in the cubital tunnel by the cubital retinaculum (formed from the ligament of Osborne and the fascia of flexor carpi ulnaris tendon).*

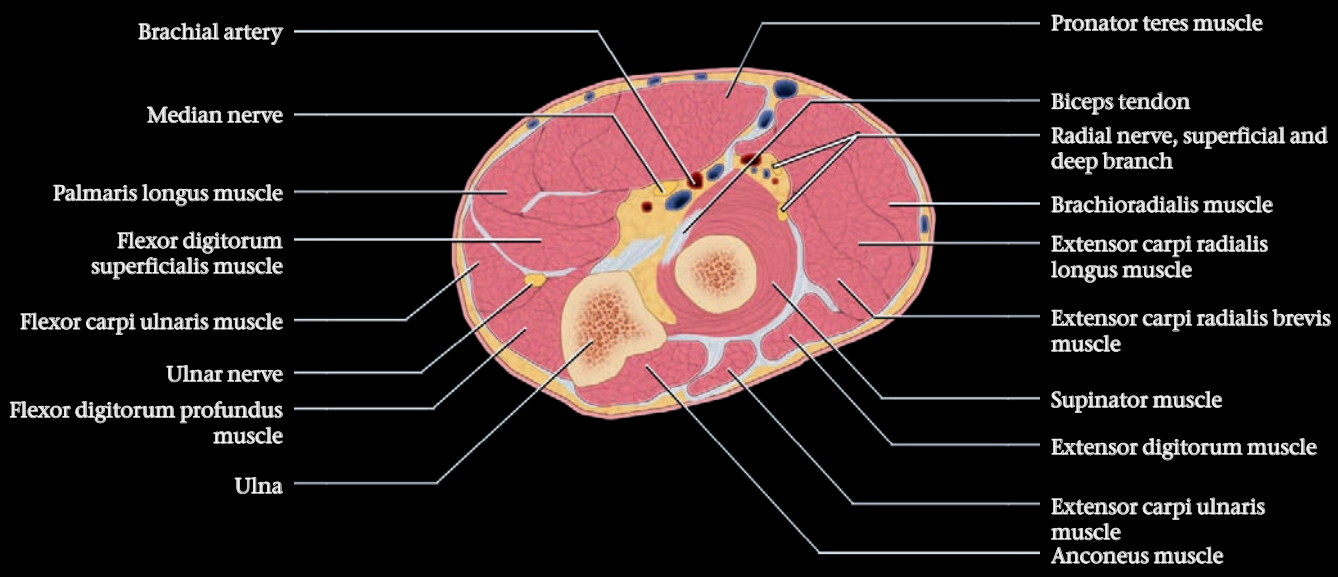
GRAPHICS, MID ELBOW CROSS SECTION

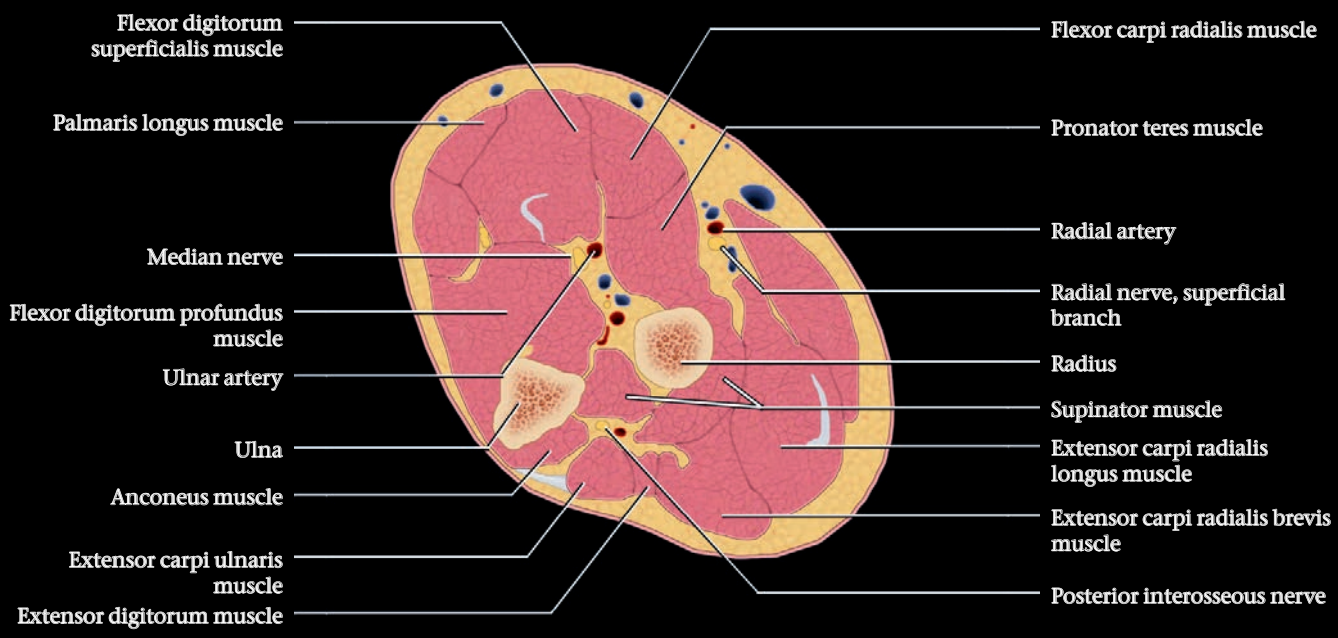


*(**Top**) Axial graphic immediately proximal to the elbow joint is shown. The common extensor tendon overlies the radial collateral ligament and may be difficult to distinguish at this level. The ulnar nerve has exited the cubital tunnel and is entering the flexor carpi ulnaris. (**Bottom**) Axial graphic at the level of the proximal radioulnar joint is shown. The articulating surfaces of the proximal radioulnar joint are well seen with the radial head being held in the radial notch of the ulna by the annular ligament. The lateral ulnar collateral ligament blends with the posterior aspect of the annular ligament.*

ELBOW

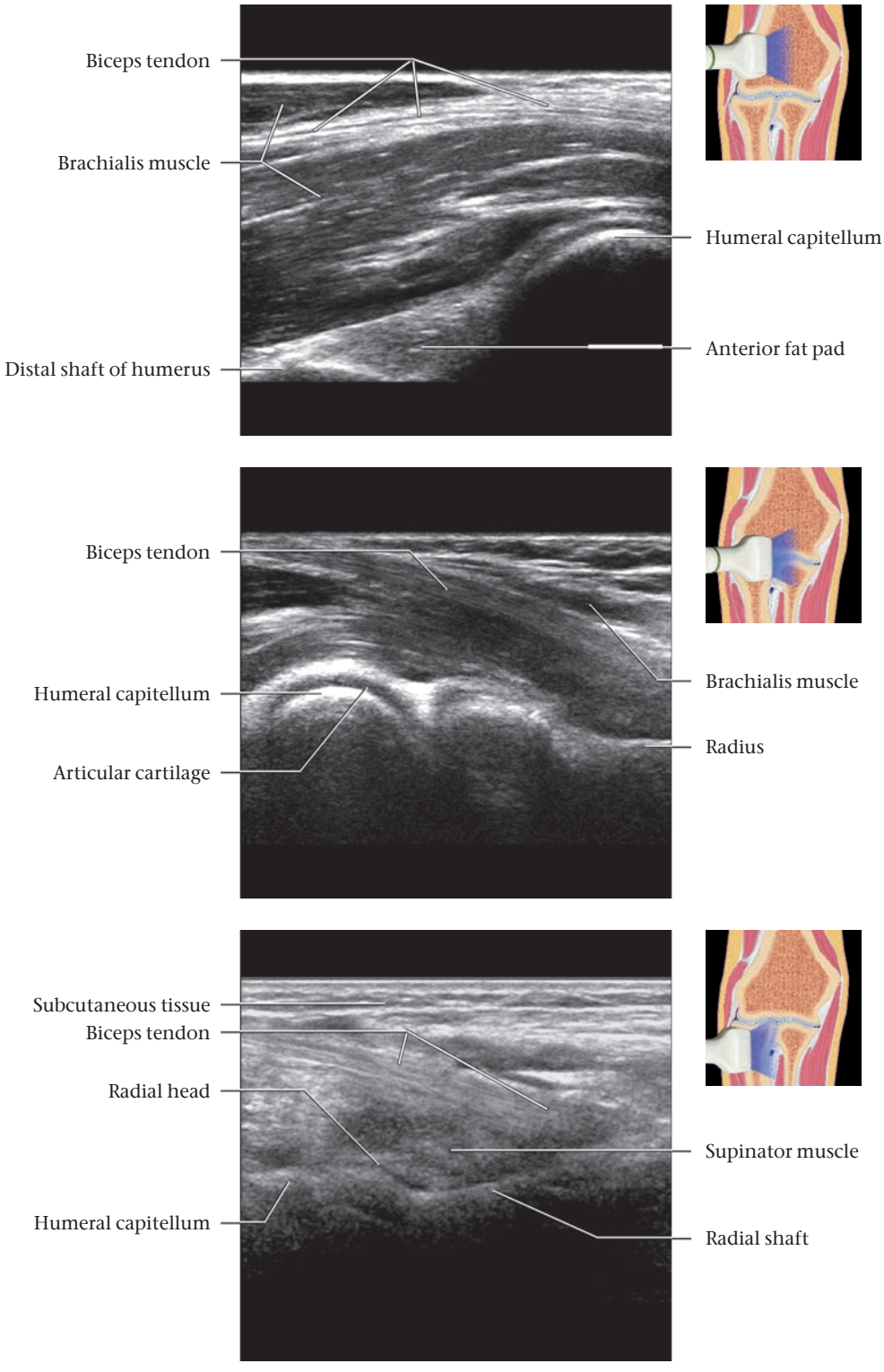
GRAPHICS, DISTAL ELBOW CROSS SECTION





(Top) *Graphic shows the axial elbow at a level immediately above the radial tuberosity. The brachialis tendon inserts on the ulnar tuberosity, and the biceps tendon approaches its insertion on the radial tuberosity, which is more distal than the brachialis insertion.* ***(Bottom)*** *At the level of the proximal forearm, the muscles are starting to align themselves into the anterior (flexor) compartment and the posterior (extensor) compartment.*

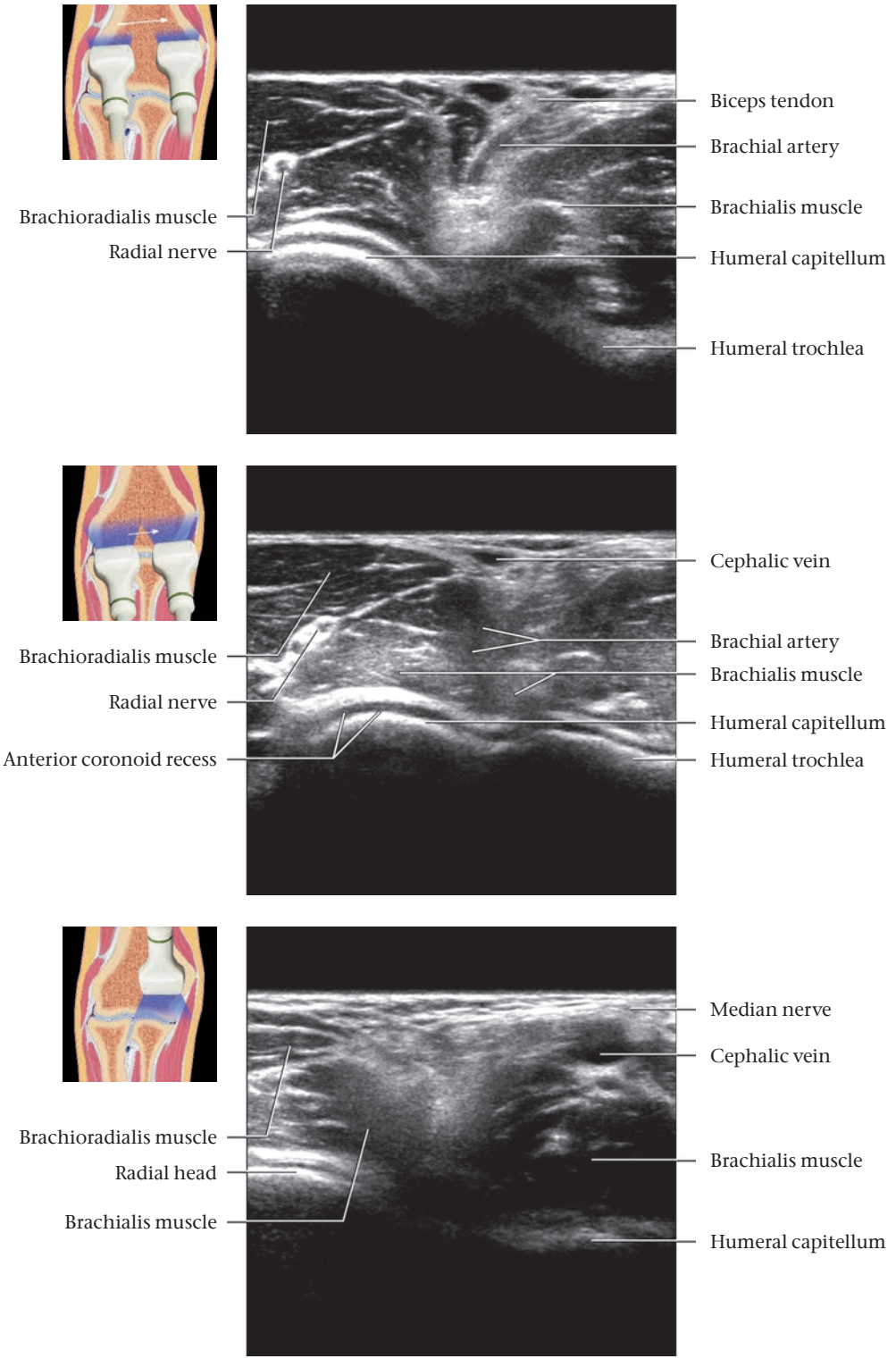
LONGITUDINAL US, ANTERIOR ELBOW



(Top) *Longitudinal grayscale ultrasound shows the biceps tendon proximal to the elbow. Most biceps tendon tears occur near the shoulder. Tears of the distal end of the biceps tendon are uncommon and mostly occur when unexpected force is applied to the bent arm.* ***(Middle)*** *Longitudinal grayscale ultrasound shows the biceps tendon at the elbow. With a torn biceps tendon, a bulge in the arm ("Popeye" muscle) may appear.* ***(Bottom)*** *Longitudinal grayscale ultrasound shows the biceps tendon just distal to the elbow. The biceps tendon flattens and rotates 90° as it approaches the insertion into the posterior aspect of the radial tuberosity. The distal biceps tendon is best visualized on longitudinal section with the forearm fully supinated. To see the insertional area of distal biceps tendon, fully pronate the forearm and flex the elbow with transducer placed posteriorly over the radial tuberosity.*

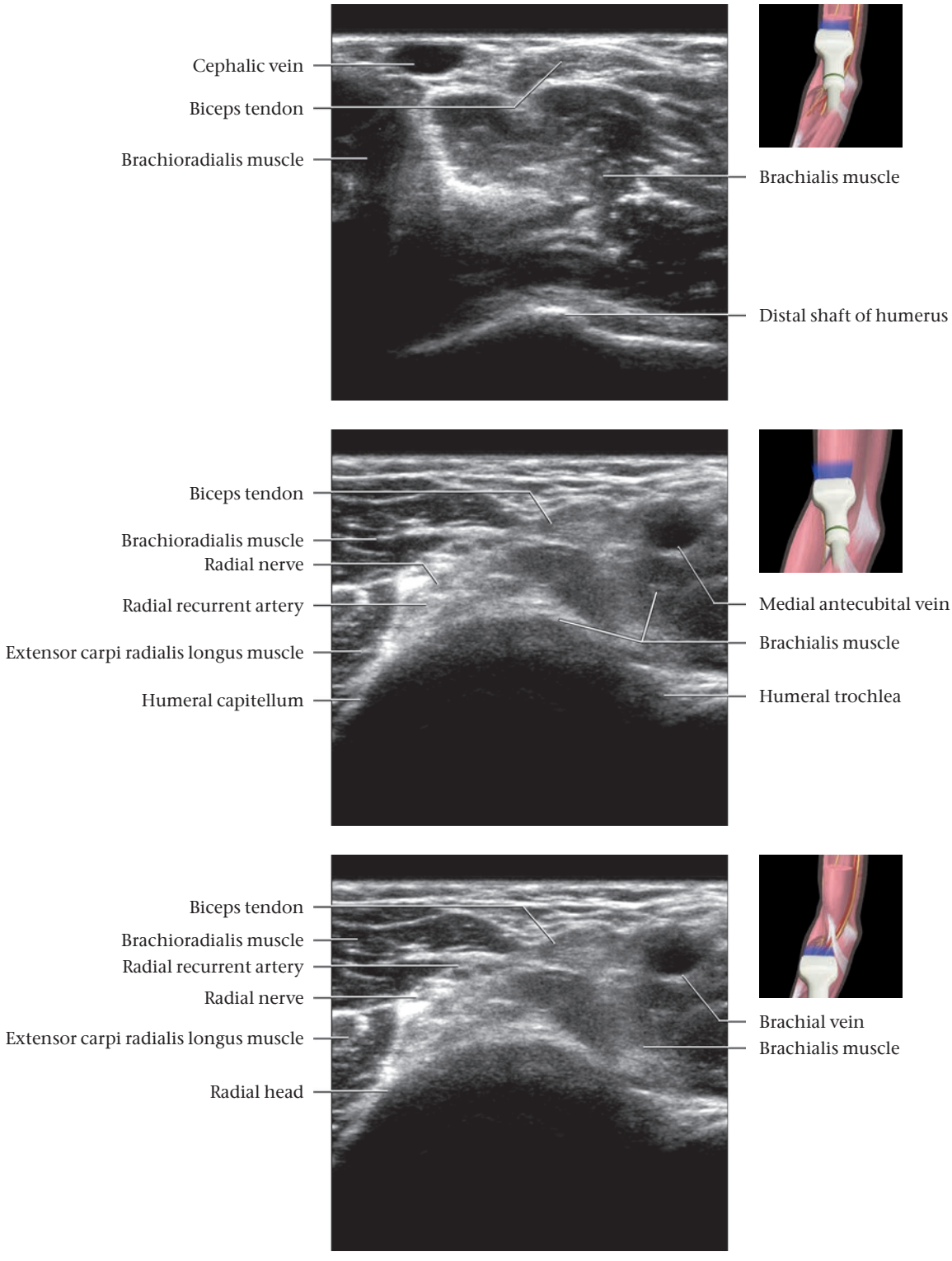
ELBOW

TRANSVERSE US, ANTERIOR ELBOW



(Top) *Transverse grayscale ultrasound shows the proximal end of the antecubital fossa. Flexion and extension occur at the humero-ulnar articulation while pronation and supination involve pronation of the radius around the ulna.* ***(Middle)*** *Transverse grayscale ultrasound shows the midportion of the antecubital fossa. The median cubital vein unites the cephalic vein with the basilic vein. It is often used for venipuncture and venous access. It lies superficial to the bicipital aponeurosis.* ***(Bottom)*** *Transverse grayscale ultrasound shows the distal aspect of the antecubital fossa. The elbow joint is supplied by arteries from the profunda brachii, the brachial arteries, and recurrent branches of the radial and ulnar arteries.*

TRANSVERSE US, ANTECUBITAL FOSSA

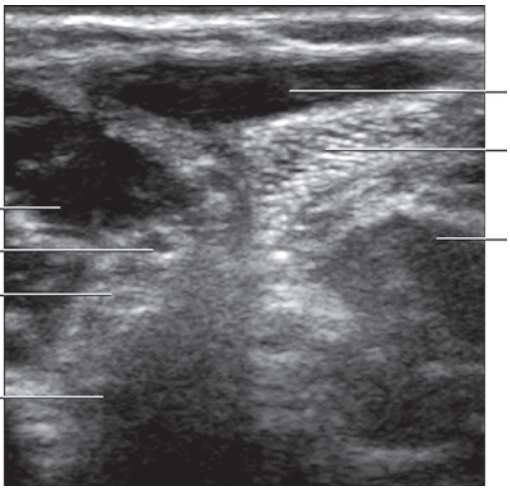


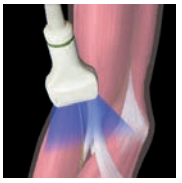
(Top) *Transverse grayscale ultrasound shows the anterior elbow and proximal antecubital fossa. The antecubital fossa or cubital fossa is the area anterior to the elbow joint.* ***(Middle)*** *Transverse grayscale ultrasound shows the antecubital fossa at the midportion. The antecubital fossa contains the radial nerve, the biceps brachii tendon, the brachial artery, and the median nerve from lateral to medial orientation.* ***(Bottom)*** *Transverse grayscale ultrasound shows the distal antecubital fossa. The bicipital aponeurosis forms the roof of the antecubital fossa. The superficial veins of the elbow lie above the bicipital aponeurosis.*

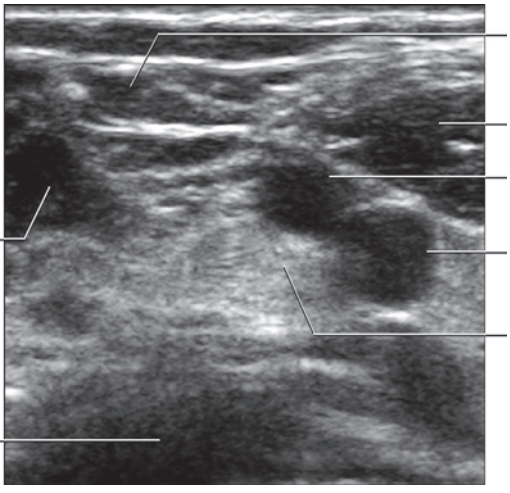
ELBOW

BICEPS TENDON

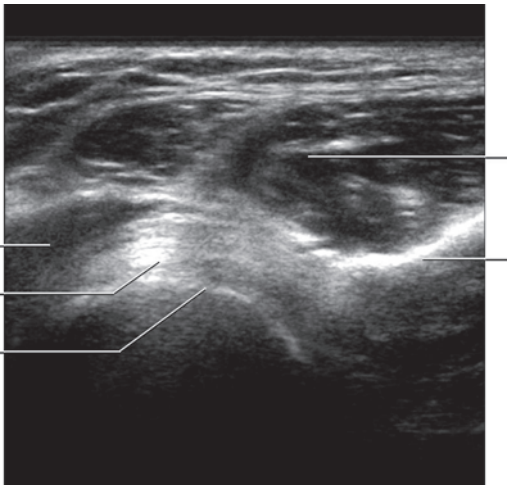






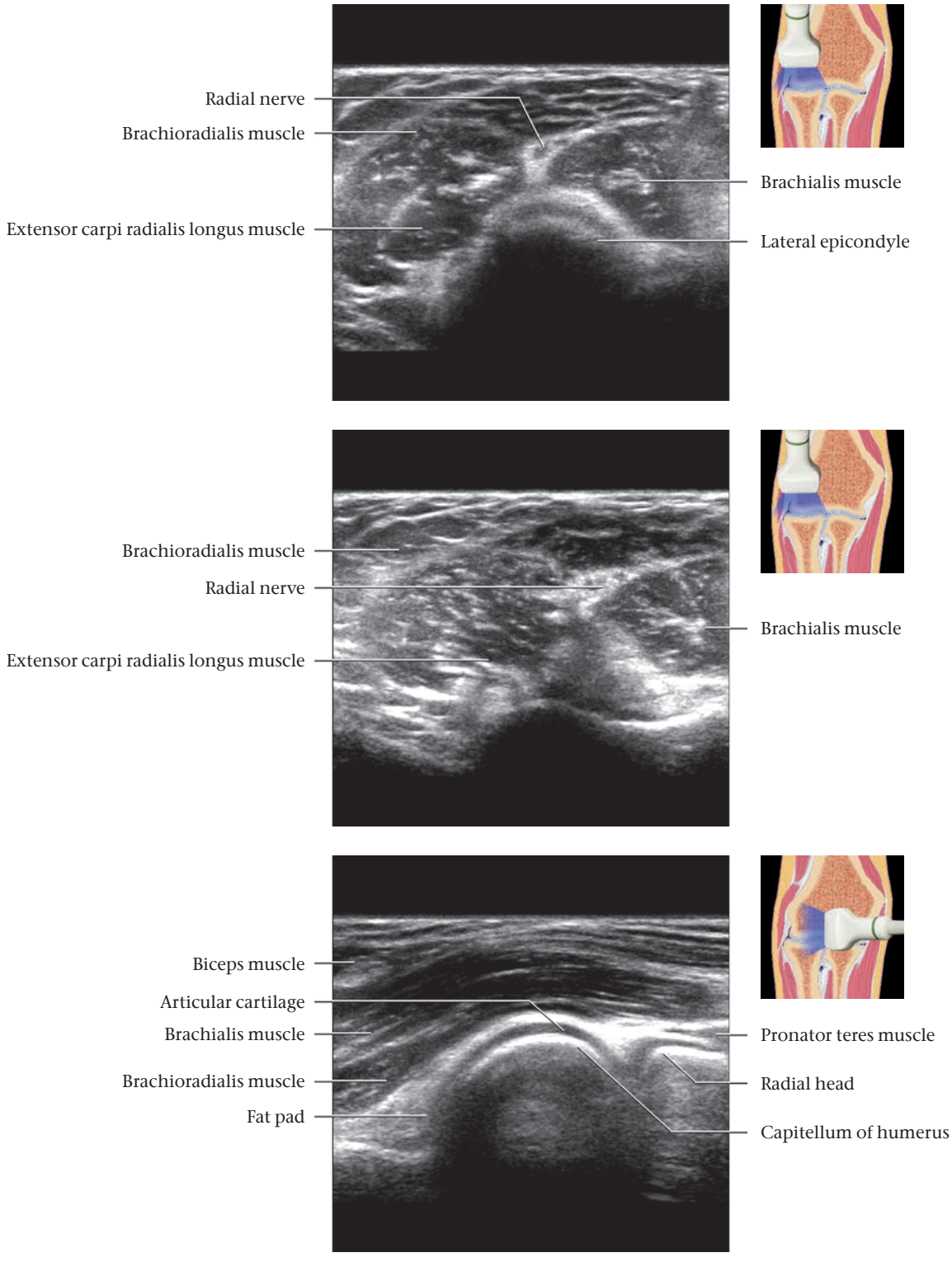






(Top) *Transverse grayscale ultrasound shows the biceps tendon at the upper antecubital fossa. The biceps tendon forms a few centimeters above the elbow joint.* ***(Middle)*** *Transverse grayscale ultrasound shows the biceps tendon at the midcubital fossa. The biceps tendon dips deeply and rotates as it passes to its insertion. The distal aspect of the biceps tendon and the insertion is difficult to see on ultrasound of the anterior surface of the elbow. Maximum supination will increase its visibility.* ***(Bottom)*** *Transverse grayscale ultrasound shows the biceps tendon insertional area. The insertional area of the biceps tendon is best seen with the elbow flexed and the wrist fully pronated. This positions the radial tuberosity posteriorly, allowing the insertional area to be viewed from the posterior aspect as shown here.*

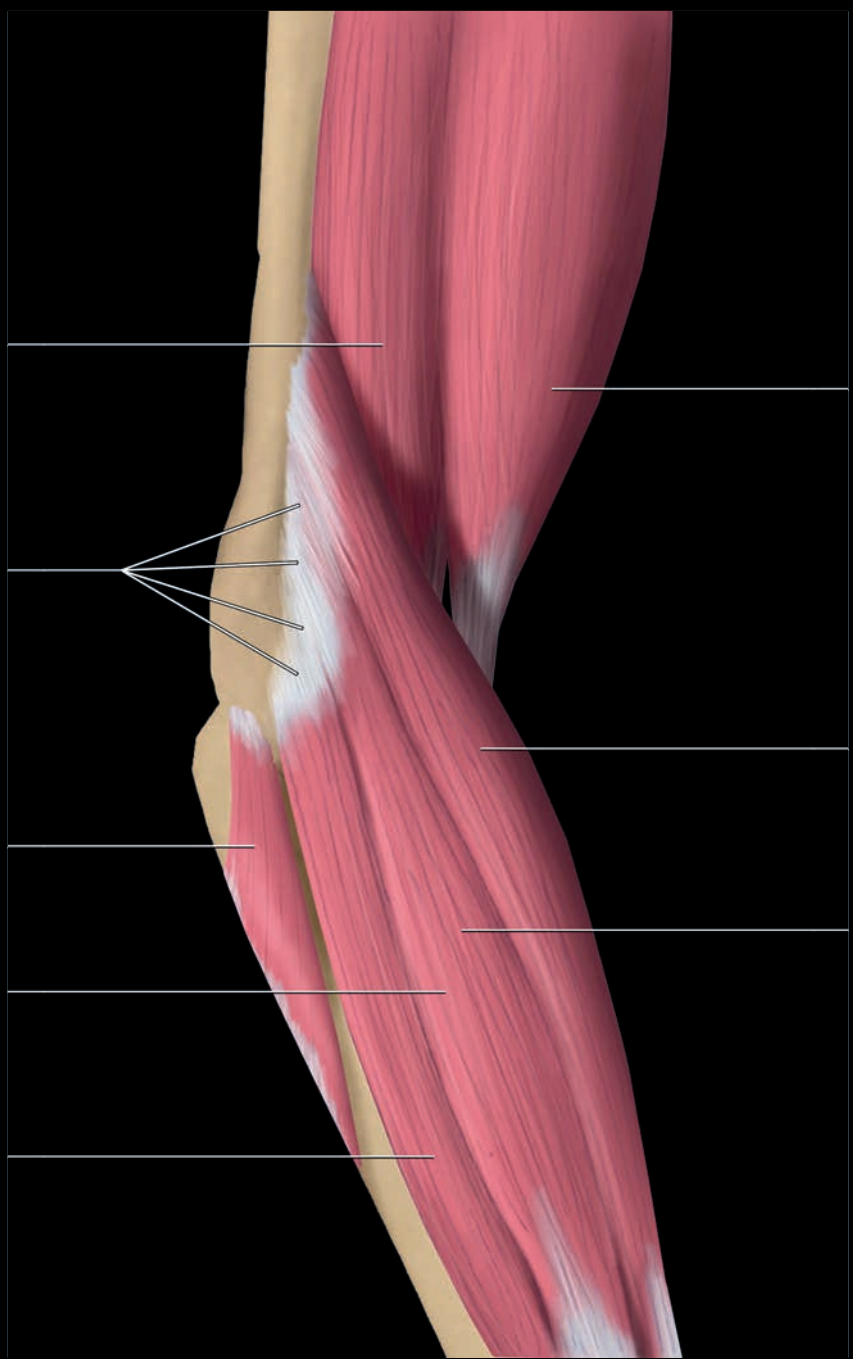
TRANSVERSE AND LONGITUDINAL US, ANTEROLATERAL ELBOW



(Top) *Transverse grayscale ultrasound shows the proximal anterolateral aspect of the elbow. The radial nerve is located on the anterolateral aspect of the elbow. It can be readily identified deep to the brachioradialis muscle.* ***(Middle)*** *Transverse grayscale ultrasound shows the midsection of the anterolateral elbow. The radial nerve passes anterior to the epicondyle deep to the brachioradialis muscle.* ***(Bottom)*** *Longitudinal grayscale ultrasound shows the anterolateral aspect of the elbow. The fat pads are intracapsular but extrasynovial. The synovial space lies deep to the fat pad on the bone surface. Distension of the fat pads allows these to become visible radiographically in elbow joint effusions.*

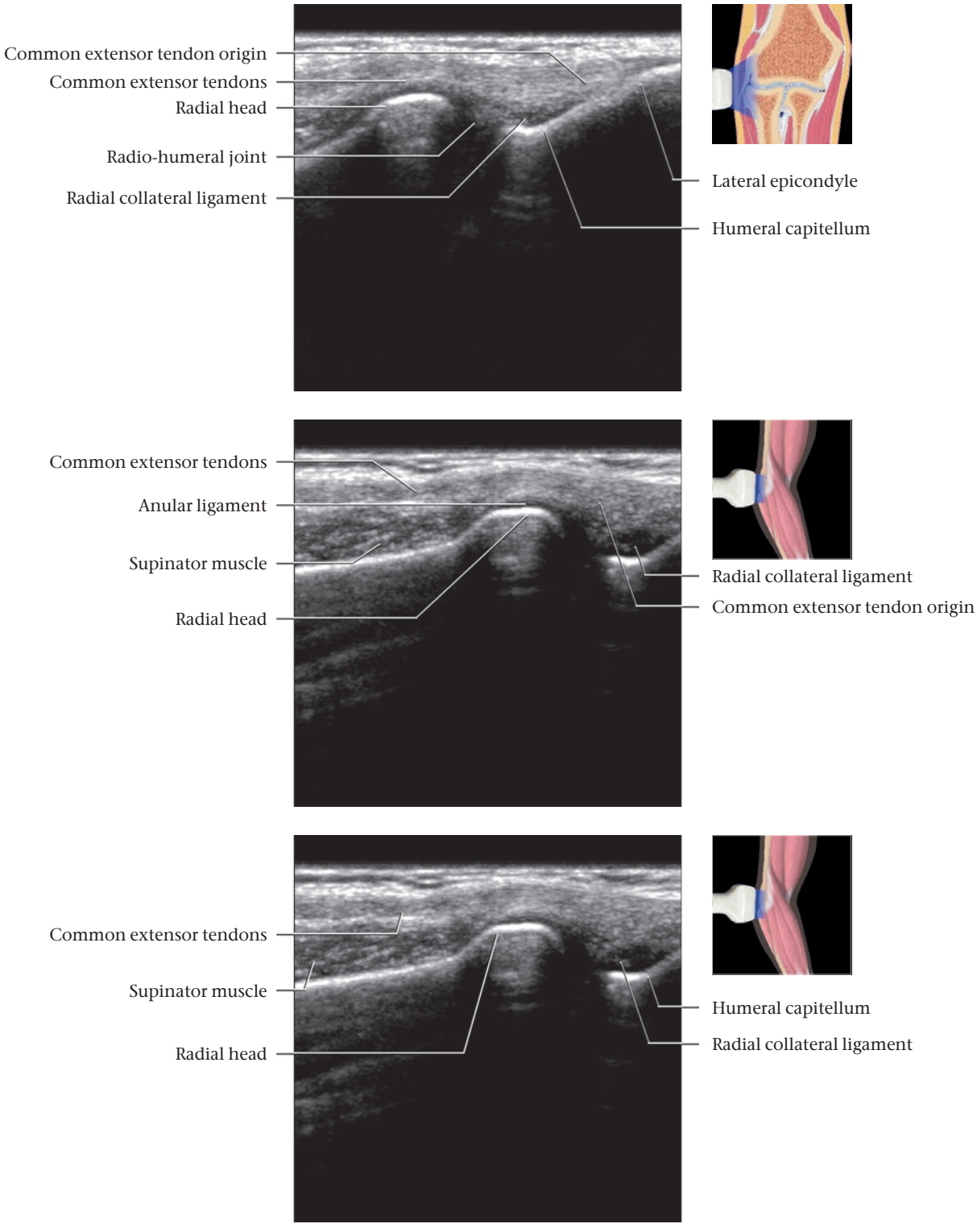
ELBOW

GRAPHIC, LATERAL ELBOW



Side view of the lateral aspect of the elbow shows the extensor-supinator group and its common extensor tendon origin, attaching to the lateral epicondyle and supracondylar aspect of the humerus. The common extensor tendon origin is composed of the extensor carpi radialis brevis, extensor digitorum, extensor digiti minimi, and extensor carpi ulnaris. The extensor digitorum origin and extensor carpi radialis brevis are very closely aligned in this section.

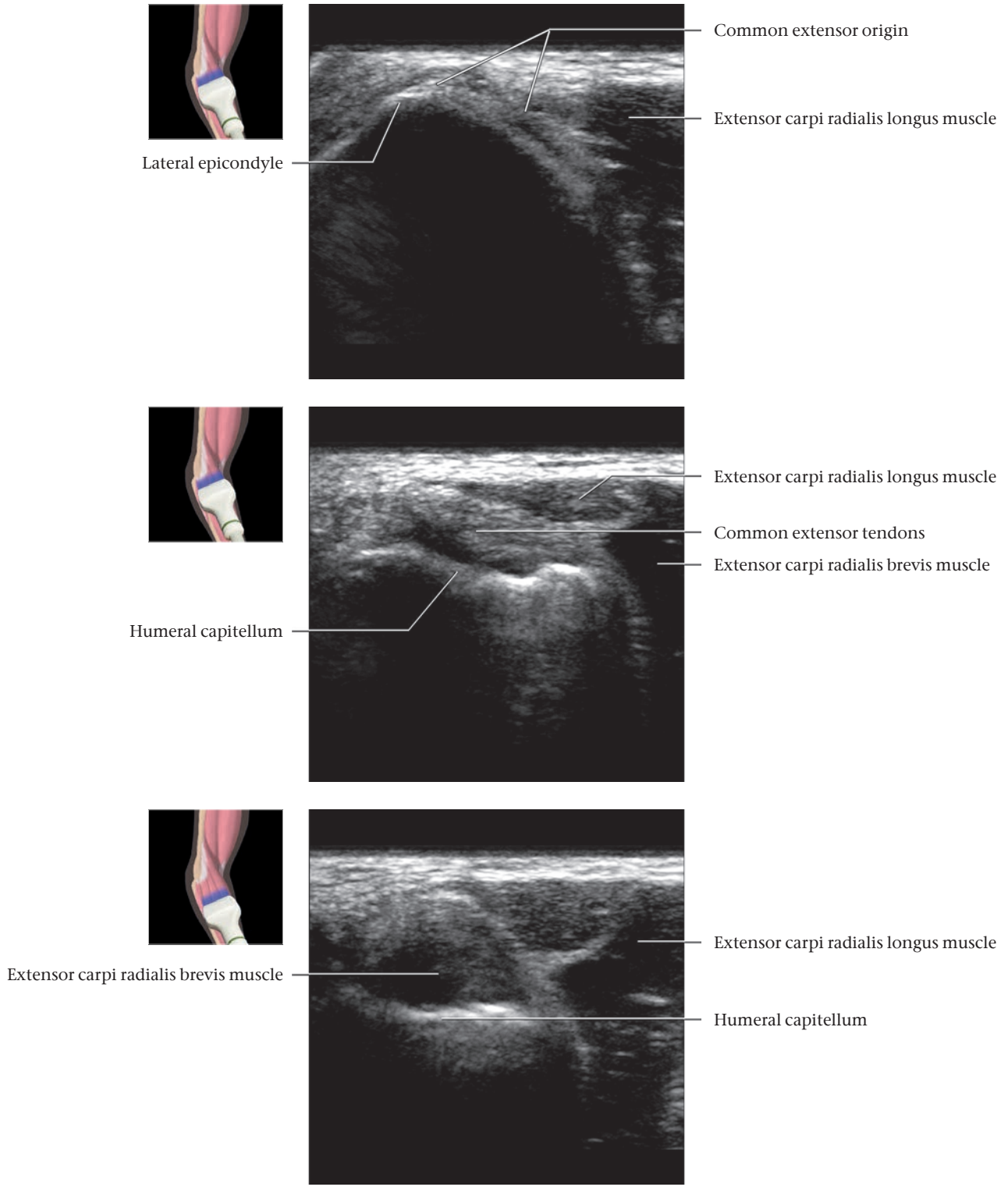
LONGITUDINAL US, COMMON EXTENSOR ORIGIN



(Top) *Longitudinal grayscale US at the common extensor tendon origin (CETO) is shown. CETO has a broad attachment on the posteroinferior aspect of the lateral epicondyle. Tendon fibers cannot be separated into individual components at or near the insertion. Fibers from extensor digitorum make up most of the superficial portion while fibers from extensor carpi radialis brevis make up most of the deep fibers. Contribution from extensor carpi ulnaris and extensor digiti minimi is only small.* ***(Middle)*** *Longitudinal grayscale US at CETO with the wrist in neutral position is shown. The radial collateral ligament is less distinct than the ulnar collateral ligament. It runs from the inferior aspect of the lateral epicondyle to gain attachment to the annular ligament.* ***(Bottom)*** *Longitudinal grayscale US at CETO with the wrist in extension is shown. Wrist extension slightly straightens extensor tendons, and dynamic movement during US can help separate movable tendons from fixed radial collateral ligament.*

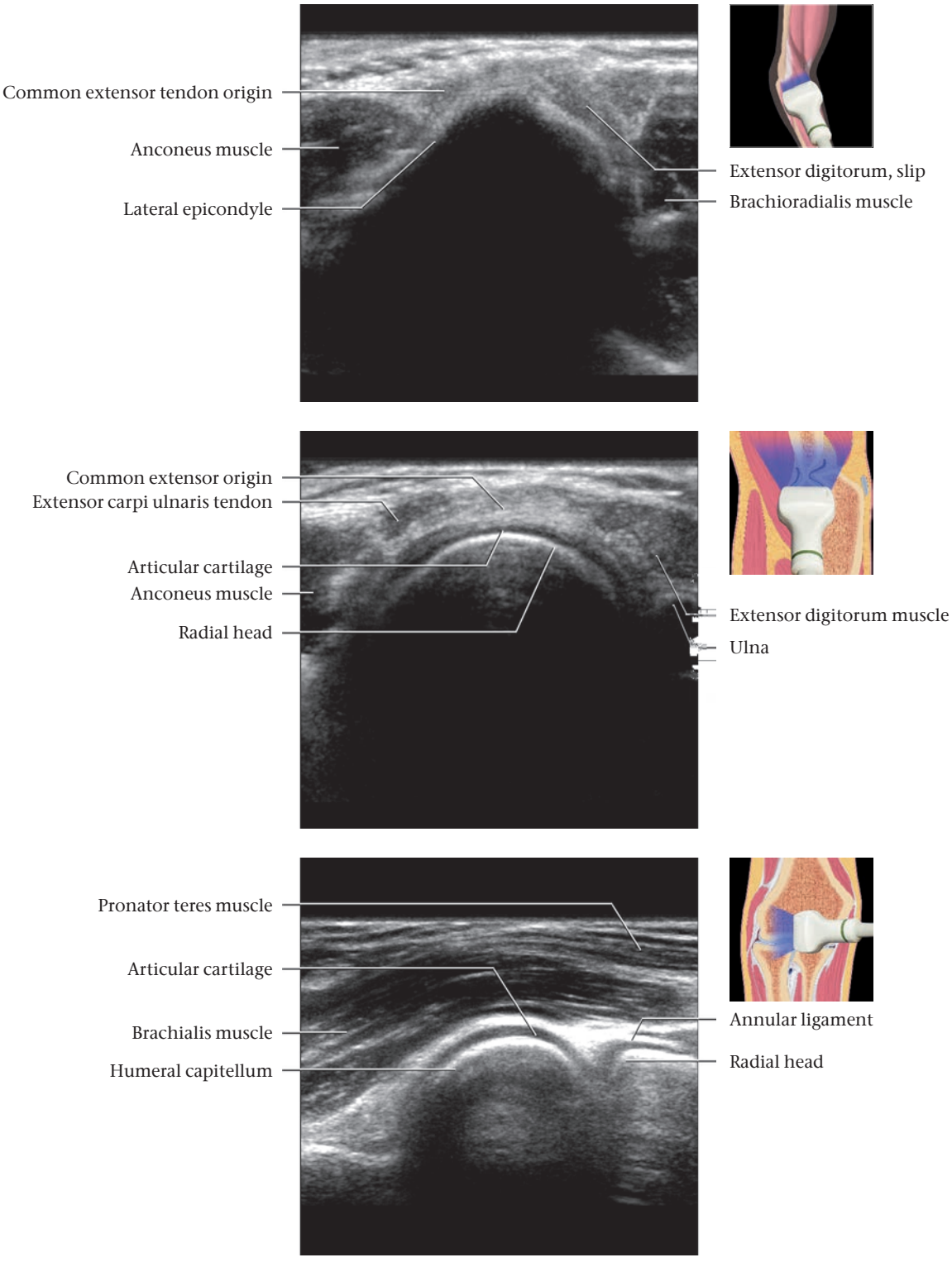
ELBOW

TRANSVERSE US, COMMON EXTENSOR TENDONS



(Top) *Transverse grayscale ultrasound shows the common extensor origin. The common extensor tendon gains broad insertion onto the posterior aspect of the lateral epicondyle.* ***(Middle)*** *Transverse grayscale ultrasound shows the common extensor origin just distal to its attachment. The tendons begin to diverge just distal to the attachment though they are not yet separate.* ***(Bottom)*** *Transverse grayscale ultrasound shows the common extensor tendons even more distal to the above section. The individual components of the common tendon origin begin to be seen near the elbow joint.*

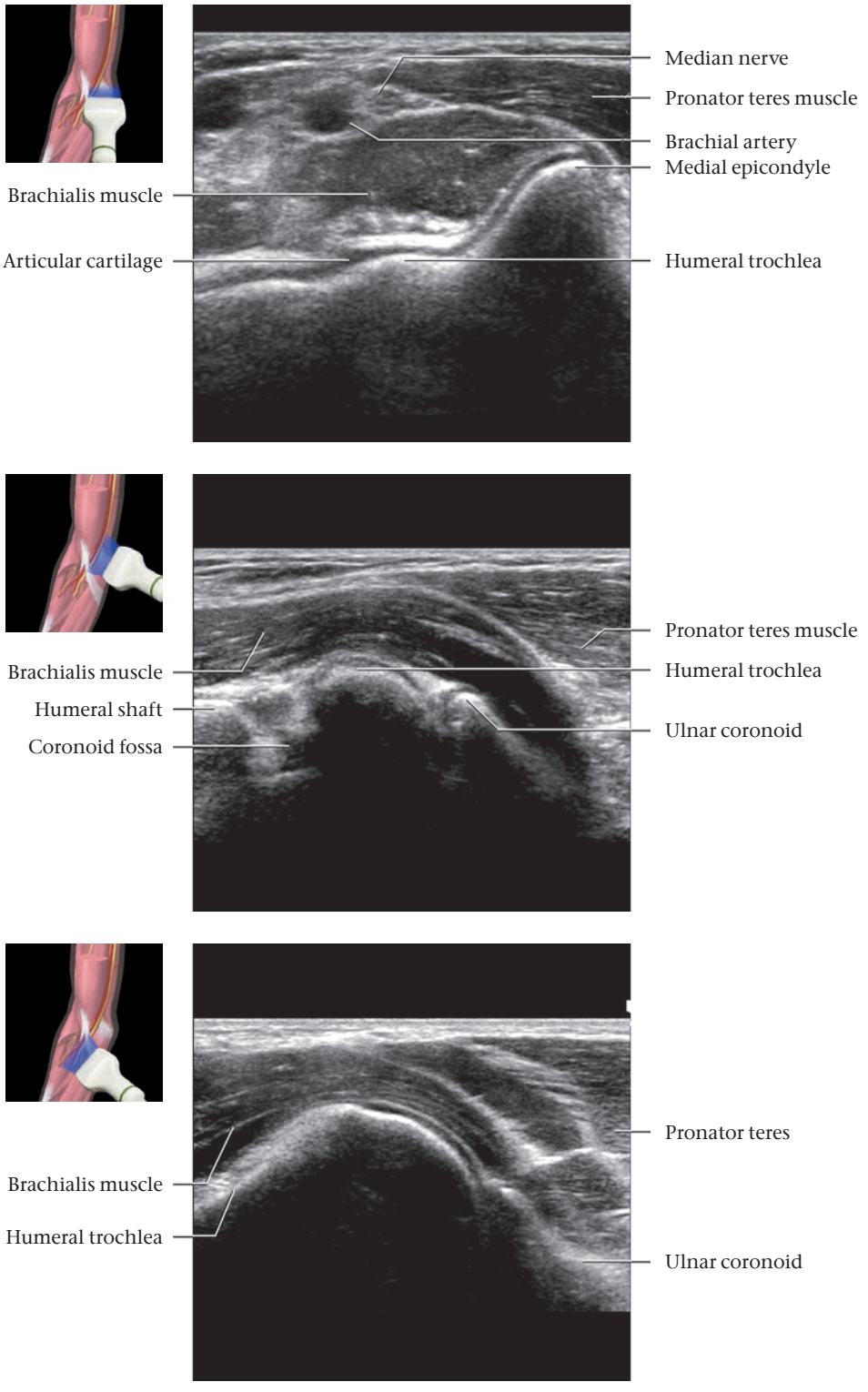
TRANSVERSE AND LONGITUDINAL US, LATERAL ELBOW



(Top) *Transverse grayscale ultrasound shows the common extensor tendon origin. The tendon caliber is often better appreciated on transverse rather than on longitudinal imaging.* ***(Middle)*** *Transverse grayscale ultrasound shows the common extensor tendons at the level of the radial head. The extensor tendons that originate from the common tendon origin can be traced distally, allowing them to be seen as separate tendons (extensor digitorum, extensor digiti minimi, extensor carpi ulnaris, and extensor carpi radialis brevis).* ***(Bottom)*** *Longitudinal grayscale ultrasound shows the common extensor tendon origin. The caliber of the common extensor tendon origin can be best appreciated on transverse imaging.*

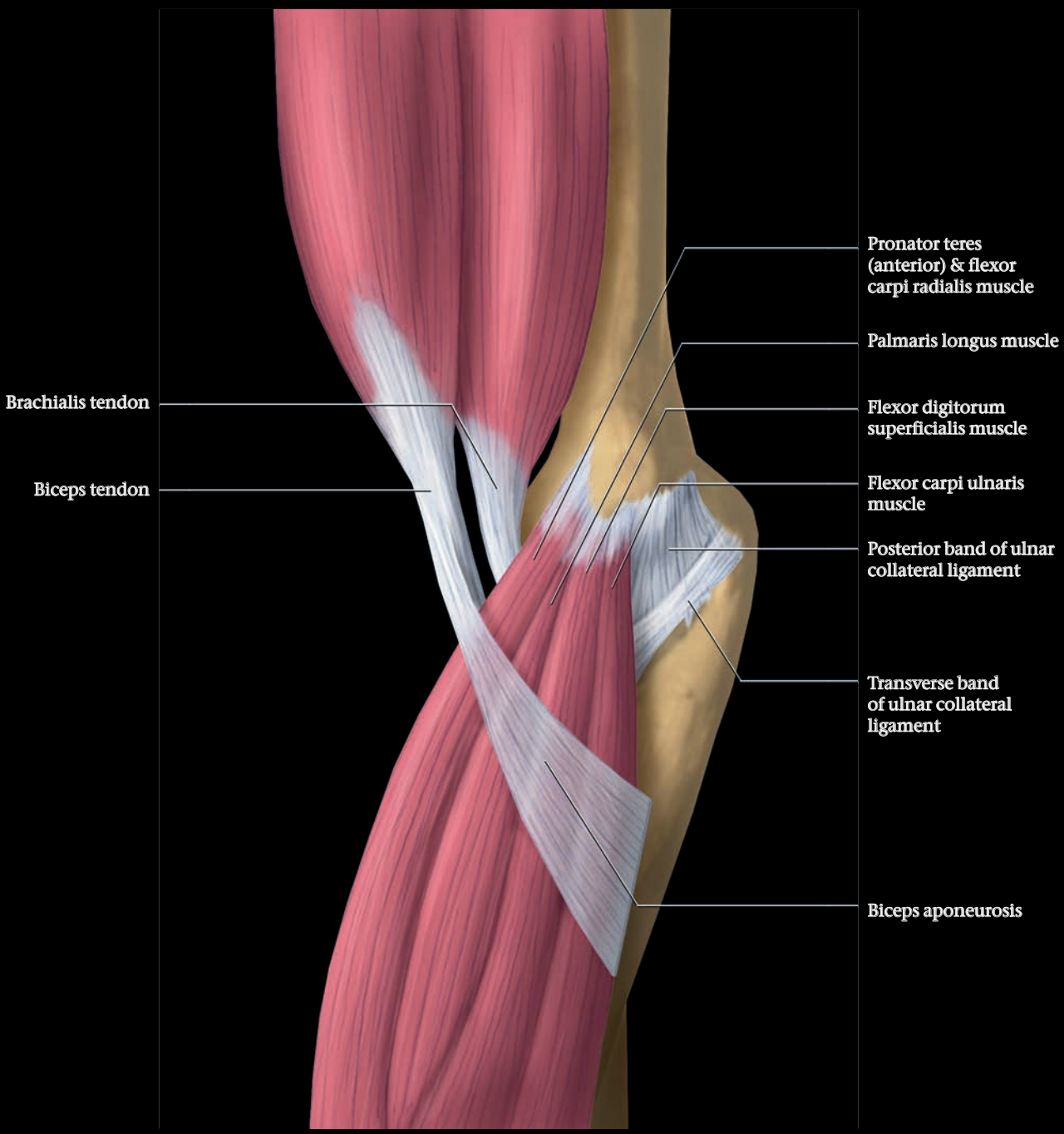
ELBOW

TRANSVERSE AND LONGITUDINAL US, ANTEROMEDIAL ELBOW



(Top) *Transverse grayscale ultrasound shows the anteromedial aspect of elbow. The pronator teres has 2 heads: 1 from the common flexor origin (medial epicondyle) and supracondylar region, and 1 from the medial side of the coronoid process. The median nerve lies deep to the pronator teres and may be trapped between these 2 heads as it enters the forearm.* ***(Middle)*** *Longitudinal grayscale ultrasound shows the anteromedial aspect of the elbow. Centrally at the junction of the distal humerus between the coronoid fossa anteriorly and the olecranon fossa posteriorly, the humerus is very thin and potentially simulating a bone defect.* ***(Bottom)*** *Longitudinal grayscale ultrasound shows the anteromedial aspect of the elbow. The brachialis muscle is closely applied to the anterior aspect of the elbow joint as it descends to its insertion on the ulnar tuberosity and the coronoid process of the ulna.*

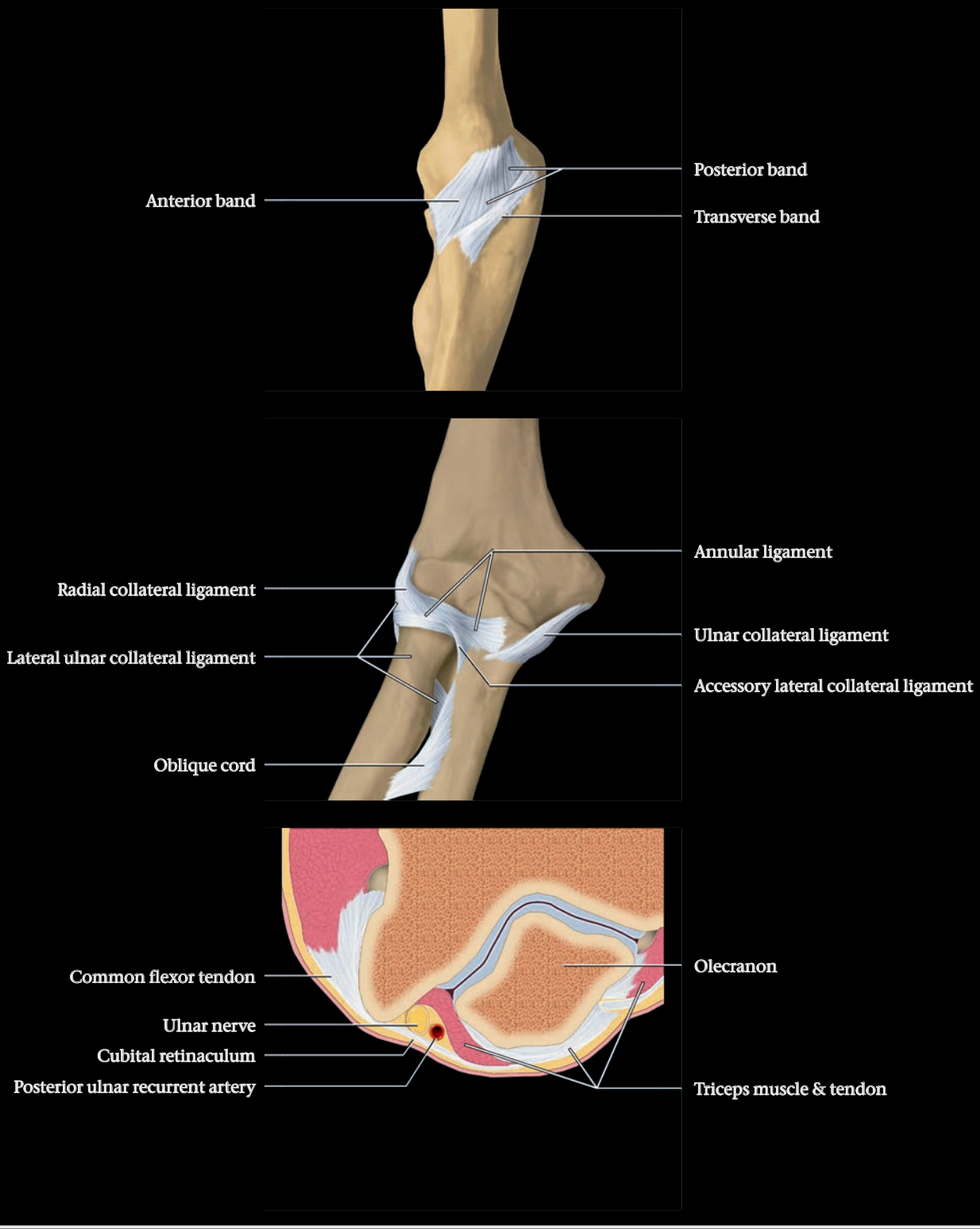
GRAPHIC, FLEXOR ASPECT



Side view of the medial aspect of the elbow shows the flexor-pronator group and its common flexor tendons, attaching to the medial epicondyle. The anterior band of the ulnar collateral ligament is deep to the common flexor tendons. The biceps aponeurosis blends with the anterior aspect of the common flexor muscle mass. The flexor digitorum profundus (not shown) arises from the proximal and midulna, posterior and deep to the flexor carpi ulnaris. It does not act on the elbow and is not part of the flexor-pronator group.

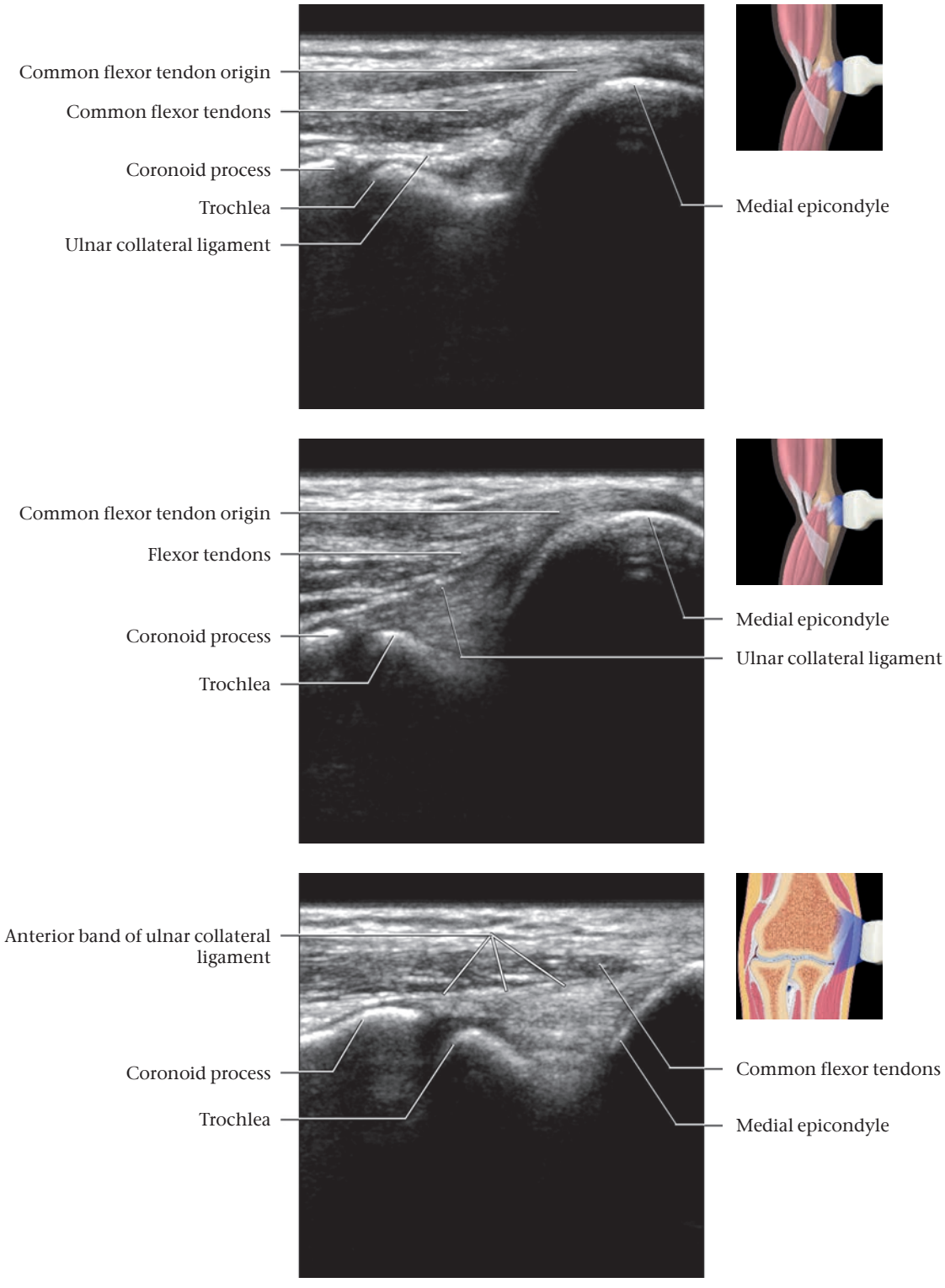
ELBOW

GRAPHICS, LIGAMENTS AROUND ELBOW



(Top) *Side view of the medial aspect of the elbow shows the 3 components of the ulnar collateral ligament: Anterior, posterior, and transverse band.* ***(Middle)*** *Anterior view of the elbow shows the radial collateral ligament complex, which is composed of radial collateral ligament (provides varus stability), lateral ulnar collateral ligament (provides posterolateral stability), annular ligament (holds radial head against radial notch of the ulna), and accessory lateral collateral ligament (reinforces annular ligament). The oblique cord is part of the proximal radioulnar joint.* ***(Bottom)*** *Axial graphic shows the cubital tunnel. The ulnar nerve may be compressed within the cubital tunnel (cubital tunnel syndrome) by a mass, post-traumatic osseous deformity, or aneurysm of the recurrent ulnar artery. The ulnar nerve may also sublux out of the cubital tunnel leading to a low grade traumatic neuritis and symptoms of carpal tunnel syndrome.*

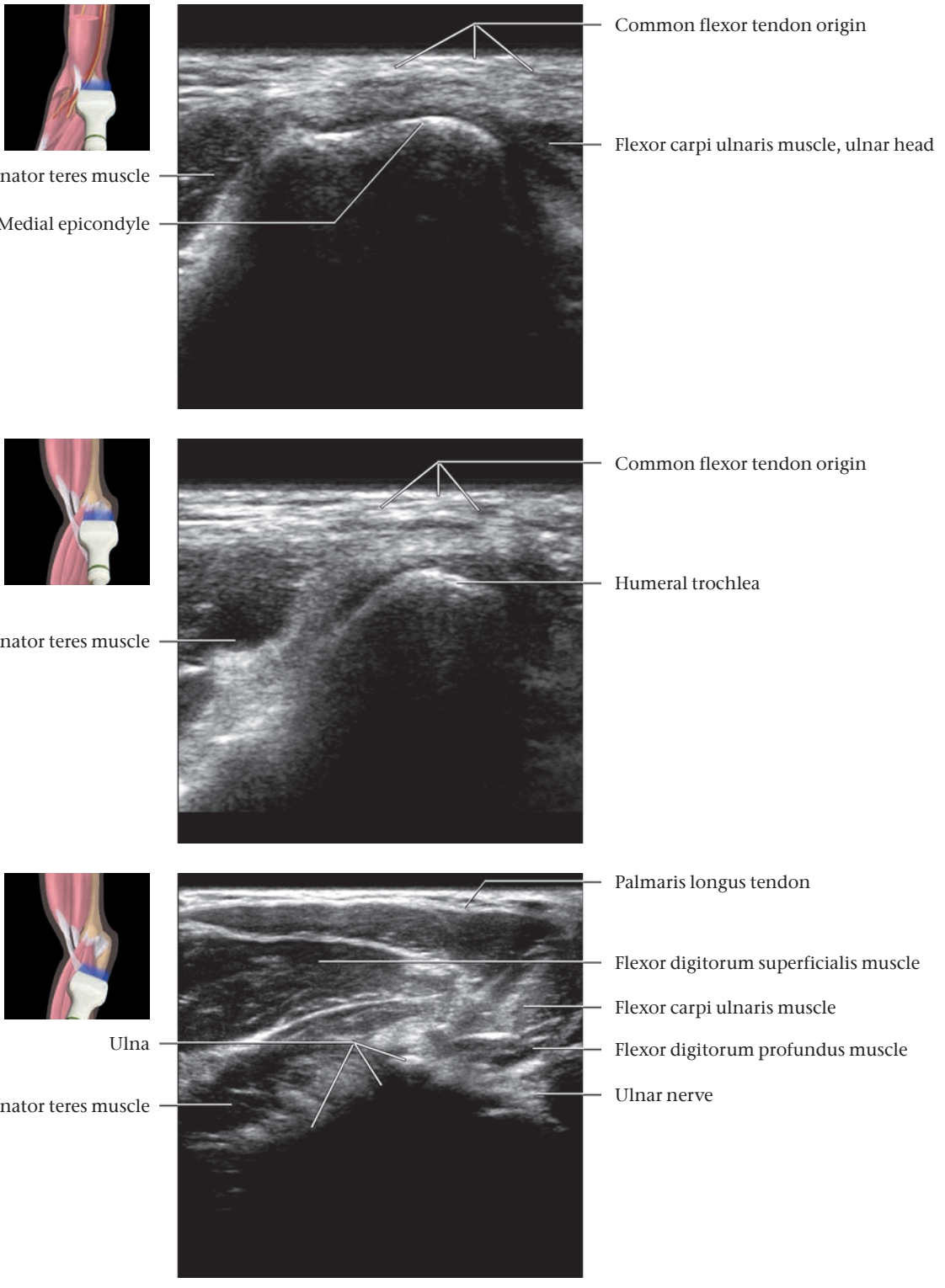
LONGITUDINAL US, COMMON FLEXOR ORIGIN



(Top) *Longitudinal grayscale ultrasound shows the common flexor tendon origin. These tendons (pronator teres, flexor carpi radialis, palmaris longus, flexor digitorum superficialis, flexor carpi ulnaris) are inseparable at or close to the origin.* ***(Middle)*** *Longitudinal grayscale ultrasound shows the ulnar collateral ligament. The ulnar collateral ligament runs from the medial epicondyle to the coronoid process. The ulnar collateral ligament lies just deep to the flexor tendons and may be injured along with these tendons.* ***(Bottom)*** *Longitudinal grayscale ultrasound shows the ulnar collateral ligament anterior band. The anterior band (medial epicondyle-sublime tubercle) is the strongest component of the ulnar collateral ligament.*

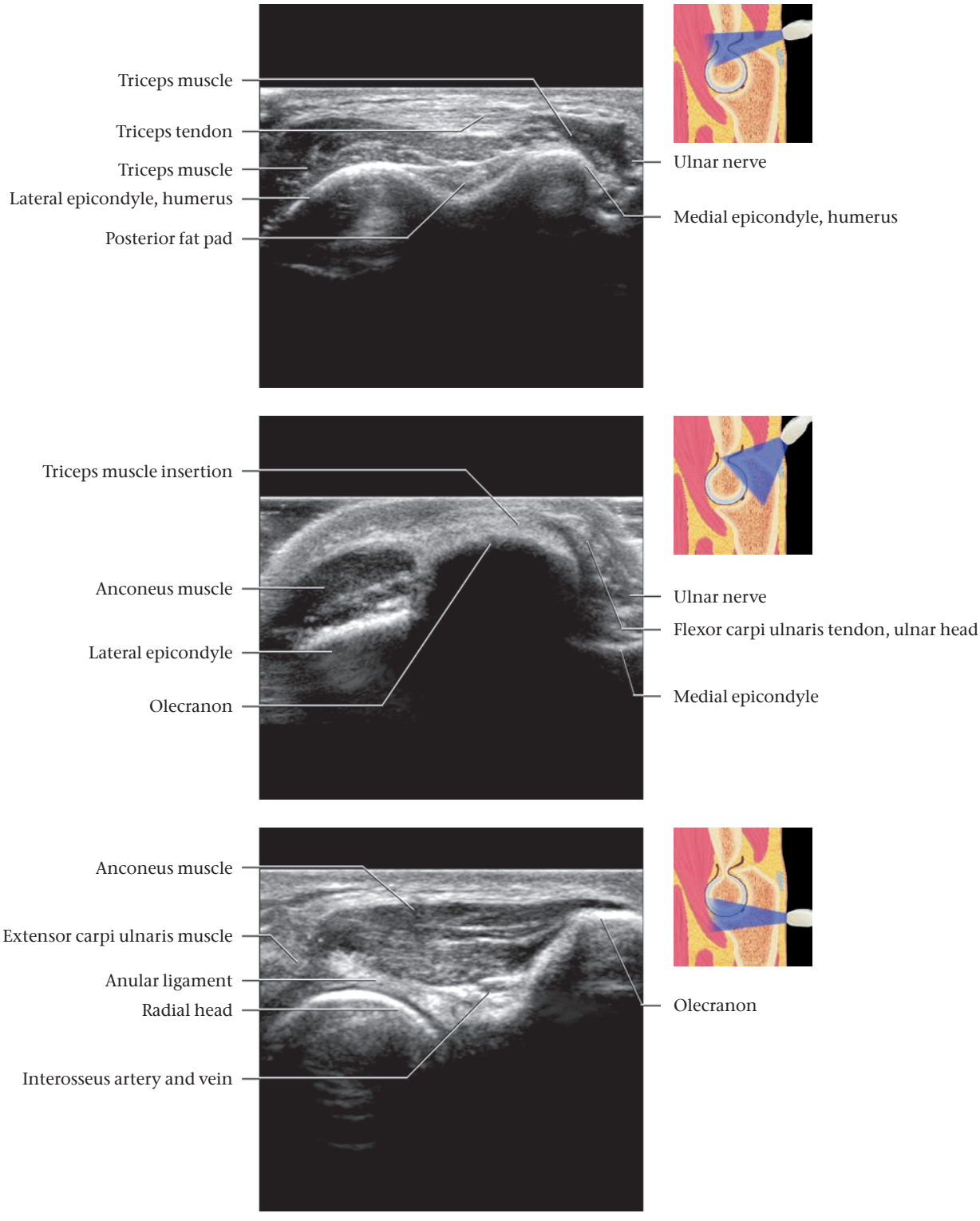
ELBOW

TRANSVERSE US, COMMON FLEXOR ORIGIN



(Top) *Transverse grayscale ultrasound shows the common flexor tendon origin. Tendinosis of the common flexor tendon is termed golfer's elbow, or medial epicondylitis. Yet most people who get this injury are involved in other sports, particularly tennis.* ***(Middle)*** *Transverse grayscale ultrasound shows the common flexor tendons just distal to the elbow. The different components of the common flexor tendons can be seen by following the tendon distally and proximally.* ***(Bottom)*** *Transverse grayscale ultrasound shows the forearm more distal to the common flexor origin.*

TRANSVERSE US, POSTERIOR ELBOW



(Top) *Transverse grayscale ultrasound shows the posterior elbow. There are 3 fat pads in the elbow: 2 anterior fat pads (radial and coronoid fossa) and 1 posterior fat pad (olecranon fossa). The synovium extends from the articular surface of the humerus and lines these fossae, i.e., it lies deep to the fat pads, which are enclosed by the elbow capsule. The fat pads therefore are intraarticular but extrasynovial. Fluid distension of the synovial cavity elevates the fat pads.* ***(Middle)*** *Transverse grayscale ultrasound shows the elbow at the level of the olecranon. The anconeus is a small muscle on the posterior aspect of the elbow that extends from the lateral epicondyle to the olecranon.* ***(Bottom)*** *Transverse grayscale ultrasound shows the proximal radioulnar joint. The annular ligament is attached to the anterior and posterior margins of the radial notch of the ulna.*

FOREARM

IMAGING ANATOMY

Flexors

- Deep flexor group
  - Flexor digitorum profundus (FDP)
    - Origin: Proximal ulna
    - Insertion: Index, middle, ring, and little finger distal phalangeal bases
  - Flexor pollicis longus (FPL)
    - Origin: Radius, interosseous membrane, coronoid process
    - Insertion: Thumb distal phalangeal base
  - Pronator quadratus (PQ)
    - Origin: Medial distal volar ulna
    - Insertion: Lateral distal dorsal radius
- Superficial
  - Flexor carpi radialis (FCR)
    - Origin: Medial epicondyle/common flexor tendon
    - Insertion: 2nd metacarpal (MC) base; slip to 3rd MC base
  - Palmaris longus (PL)
    - Origin: Medial epicondyle/common flexor tendon
    - Insertion: Volar distal flexor retinaculum and palmar aponeurosis
  - Flexor carpi ulnaris (FCU)
    - Origin: Medial epicondyle (humeral head) and medial proximal ulna (ulnar head)
    - Insertion: Pisiform
  - Flexor digitorum superficialis (FDS)
    - Origin: Medial epicondyle and ulnar coronoid process (humeroulnar head); volar proximal radius (radial head)
    - Insertion: Middle phalanges index, middle, ring, and little fingers

Extensors

- Deep
  - Abductor pollicis longus (APL)
    - Origin: Dorsal lateral ulna, dorsal midradius
    - Insertion: 1st MC radial base
  - Extensor pollicis brevis (EPB)
    - Origin: Dorsal midradius
    - Insertion: Thumb proximal phalangeal base
  - Extensor pollicis longus (EPL)
    - Origin: Dorsal midulna
    - Insertion: Thumb distal phalanx base
    - Variant: Fused with EPB
  - Extensor indicis (EI)
    - Origin: Dorsal midulna and interosseous membrane
    - Insertion: Extensor hood of index finger
- Superficial
  - Extensor carpi radialis longus (ECRL)
    - Origin: Lateral epicondyle/common extensor tendon
    - Insertion: Dorsal radial 2nd MC
  - Extensor carpi radialis brevis (ECRB)
    - Origin: Lateral epicondyle/common extensor tendon
    - Insertion: Dorsal radial 3rd MC
  - Extensor digitorum (ED)
    - Origin: Lateral epicondyle/common extensor tendon
    - Insertion: Middle and distal phalanges of index, middle, ring, little fingers
  - Extensor digiti minimi (EDM)
    - Origin: Lateral epicondyle/common extensor tendon
    - Insertion: Extensor hood of little finger proximal phalanx with slip to ring finger
  - Extensor carpi ulnaris (ECU)
    - Origin: Common extensor tendon and dorsal ulna
    - Insertion: Dorsal ulnar 5th MC base

Anomalous Muscles

- May present as a soft tissue mass
  - May create neural compression
- Accessory palmaris longus
  - Superficial to FD tendons, medial to FCR
- Extensor digitorum manus brevis
  - Arises from distal radius or dorsal radiocarpal ligament
  - Inserts on 2nd MC
  - May be tender or present as mass
- Extensor carpi radialis intermedius
  - Arises from humerus or as accessory slip from ECRB or ECRL
  - Inserts on 2nd &/or 3rd MC
- Extensor carpi radialis accessory
  - Arises from humerus or ECRL
  - Inserts on 1st MC bone, abductor pollicis brevis (APB), or 1st dorsal interosseous muscle

ANATOMY IMAGING ISSUES

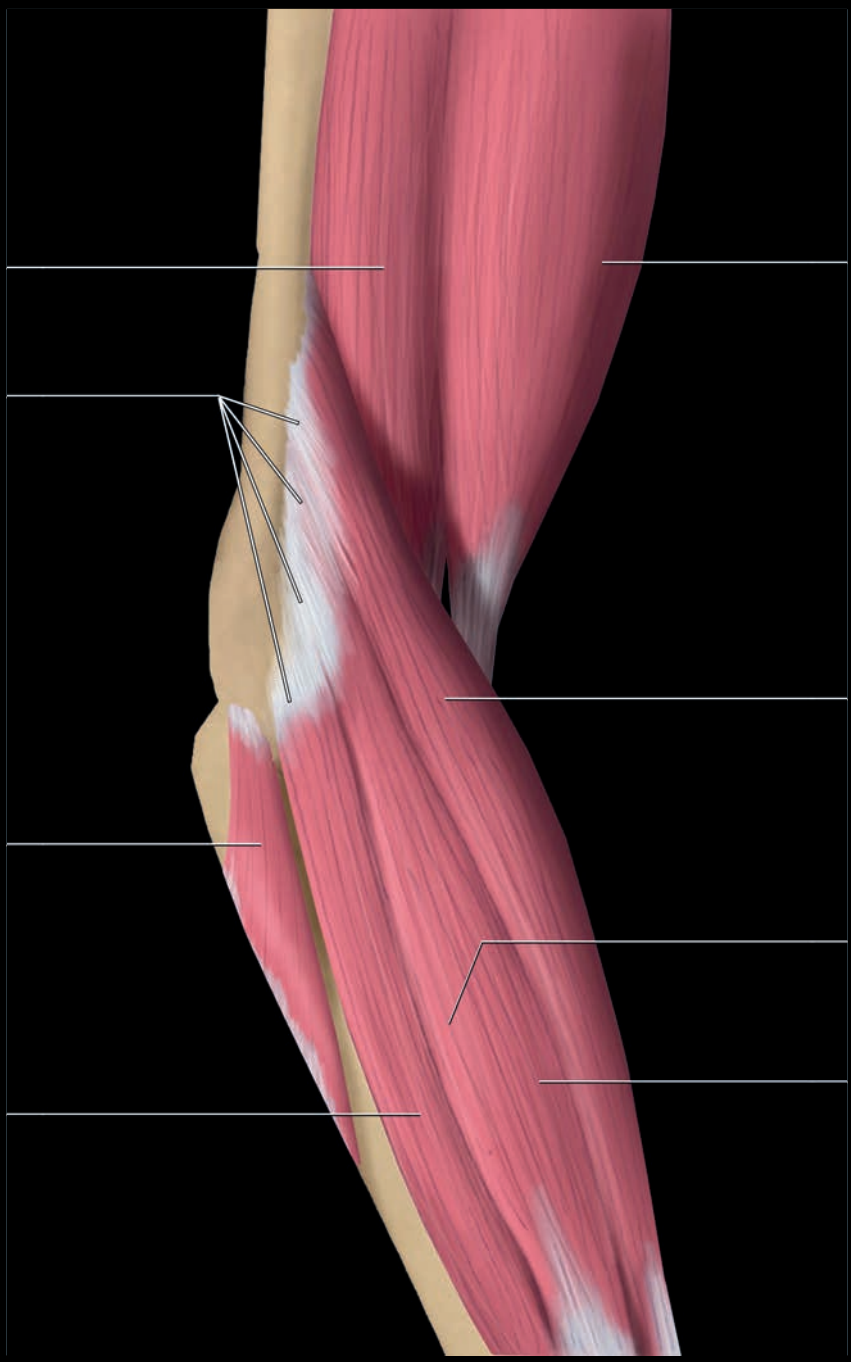
Imaging Pitfalls

- Many variations of flexor and extensor muscles and tendons
- Extensor pollicis brevis may be absent or fused with EPL
- Palmaris longus absent in 10%; short tendon with extended muscle belly may compress median nerve
- Multiple tendon slips can mimic longitudinal tendon tears (e.g., APL)
- Small amount of fluid common in tendon sheath (e.g., ECRB, ECRL, ECU)

Imaging Issues

- APL and EPB intersect ECRB and ECRL just proximal to extensor retinaculum; may impinge at musculotendinous intersection ("intersection syndrome")
- Sites of radial nerve entrapment in forearm
  - Posterior interosseous nerve within radial tunnel under arcade of Frohse
  - Posterior interosseous nerve between deep and superficial heads of supinator muscle
  - Superficial radial nerve between brachioradialis and ECRL in mid to distal forearm
- Sites of ulnar nerve entrapment in forearm
  - Cubital tunnel
  - Beyond cubital tunnel it passes between the humeral and ulnar origins of flexor carpi ulnaris muscle
- Sites of medial nerve entrapment in forearm
  - Between heads of pronator teres

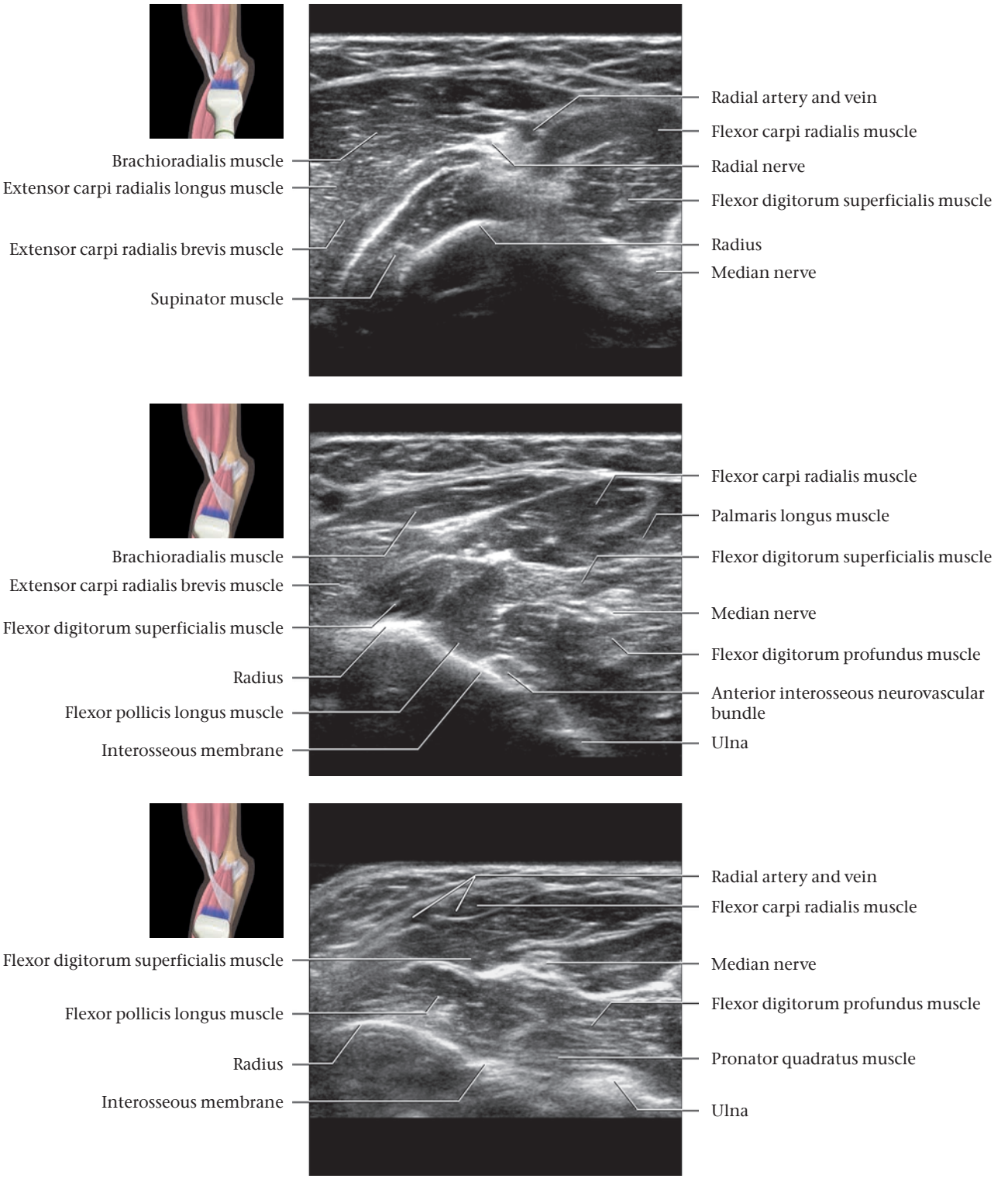
GRAPHIC, COMMON EXTENSOR TENDON



Graphic of a side view of the lateral aspect of the elbow shows the extensor-supinator group and its common extensor tendon origin attached to the lateral epicondyle and supracondylar aspect of the humerus. The common extensor tendon origin is composed of the extensor carpi radialis brevis, extensor digitorum, extensor digiti minimi, and extensor carpi ulnaris.

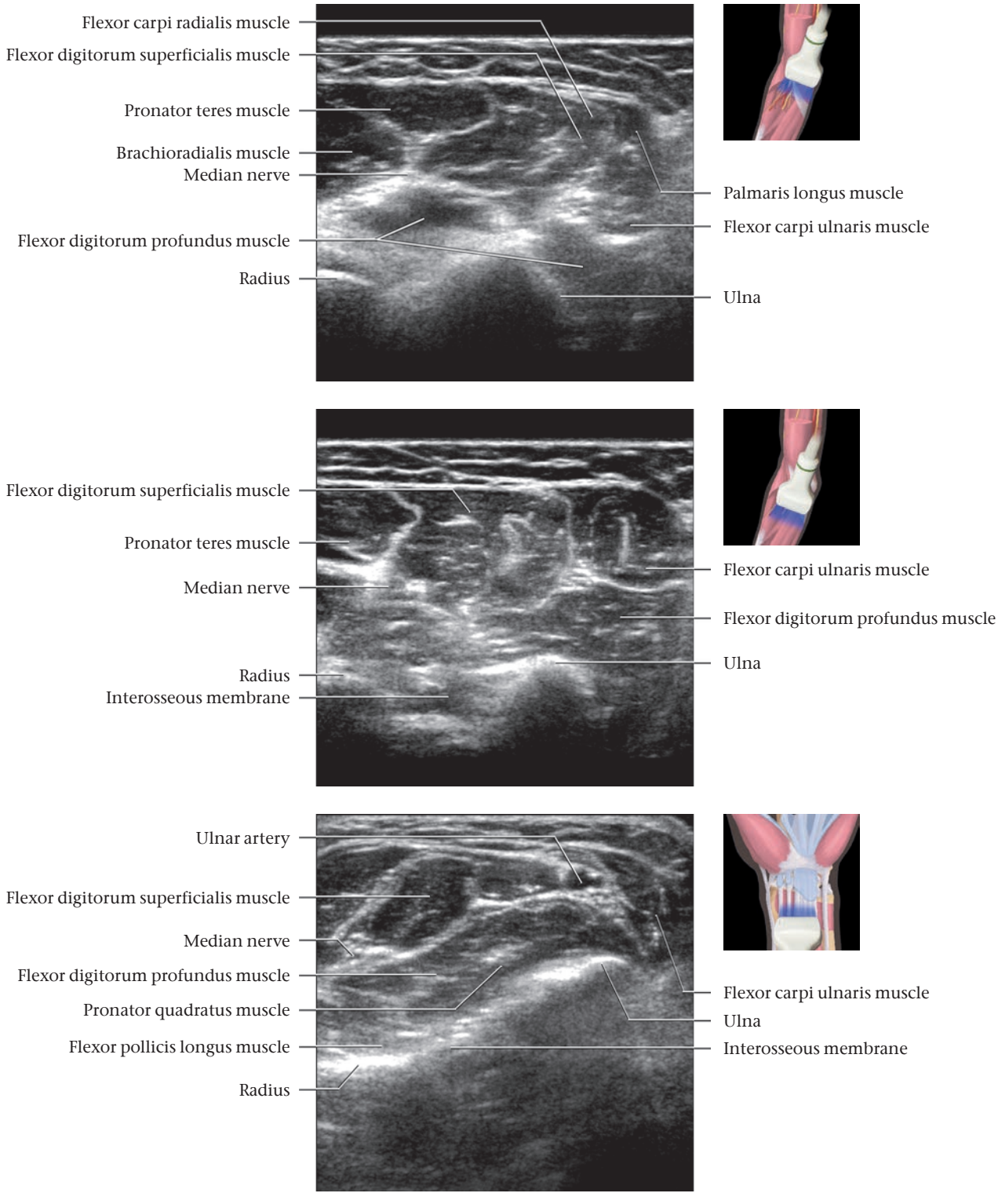
FOREARM

TRANSVERSE US, ANTERIOR FOREARM



(Top) *Transverse grayscale ultrasound shows the anterior aspect of the proximal 1/3 of the forearm. The anterior aspect of the forearm consists of 5 flexor muscles: 3 superficial and 2 deep.* ***(Middle)*** *Transverse grayscale ultrasound shows the anterior aspect of the midforearm. The 3 superficial flexor muscles are, from ulnar to radial aspect, the flexor carpi ulnaris, the flexor digitorum superficialis, and the flexor carpi radialis. The 2 deep flexor muscles are flexor digitorum profundus and flexor pollicis longus.* ***(Bottom)*** *Transverse grayscale ultrasound shows the anterior aspect distal 1/3 of the forearm. The pronator quadratus is an easily recognized muscle that helps to pronate the forearm.*

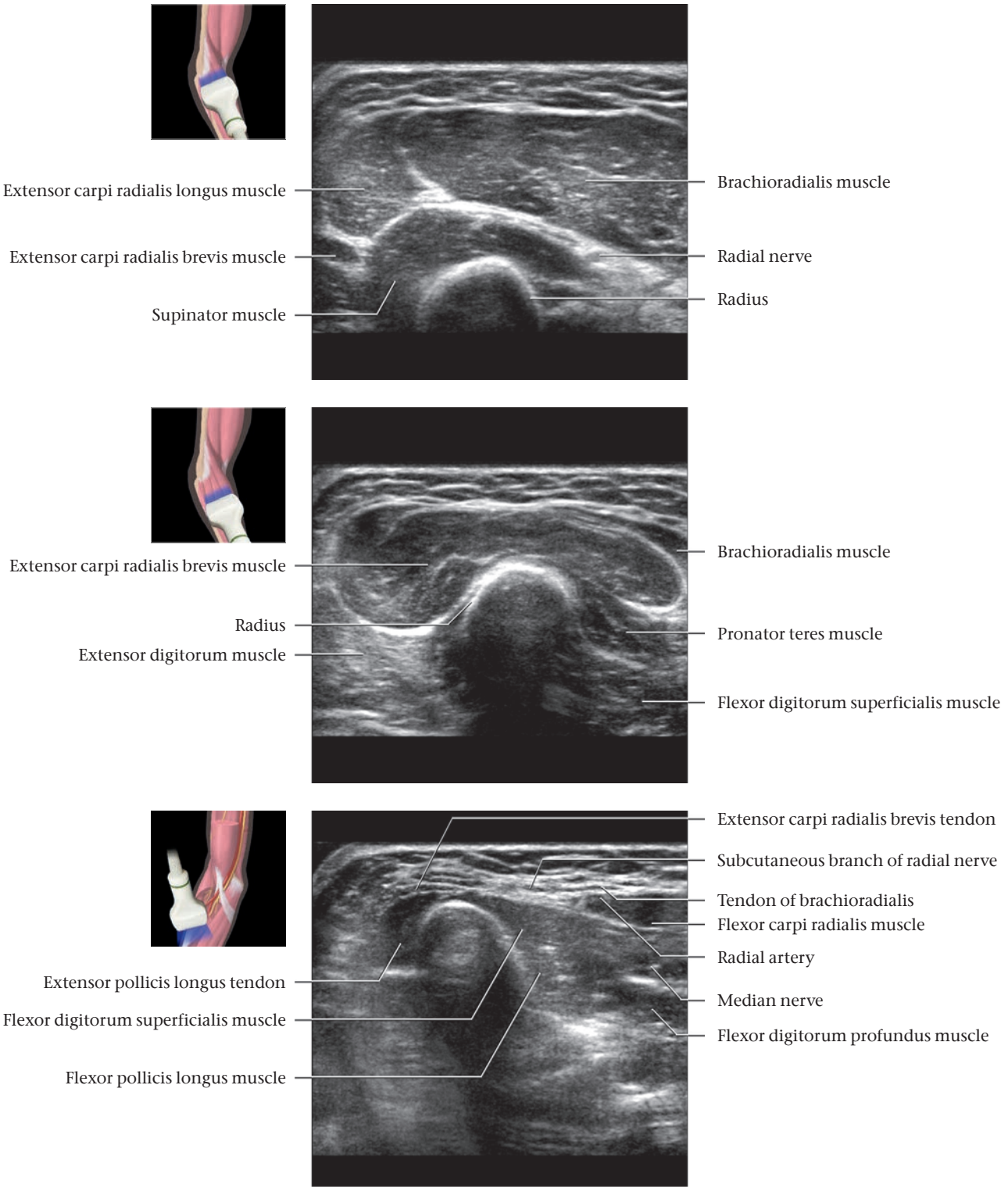
TRANSVERSE US, ANTEROMEDIAL FOREARM



(Top) *Transverse grayscale ultrasound shows the anteromedial aspect of the proximal 1/3 of the forearm. The main flexors of the wrist are contained along the anterior and anteromedial aspect of the forearm. These are divided into 2 groups: Superficial and deep.* ***(Middle)*** *Transverse grayscale ultrasound shows the anteromedial aspect of the middle 1/3 of the forearm. The superficial group consists of the flexor carpi ulnaris, the flexor digitorum superficialis, and the flexor carpi radialis. The deep group consists of the flexor digitorum profundus and the flexor pollicis longus.* ***(Bottom)*** *Transverse grayscale ultrasound shows the anteromedial aspect of the distal 1/3 of the forearm. The ulnar nerve lies deep to the flexor carpi ulnaris, while the median nerve lies between the flexor digitorum superficialis and flexor digitorum profundus muscles.*

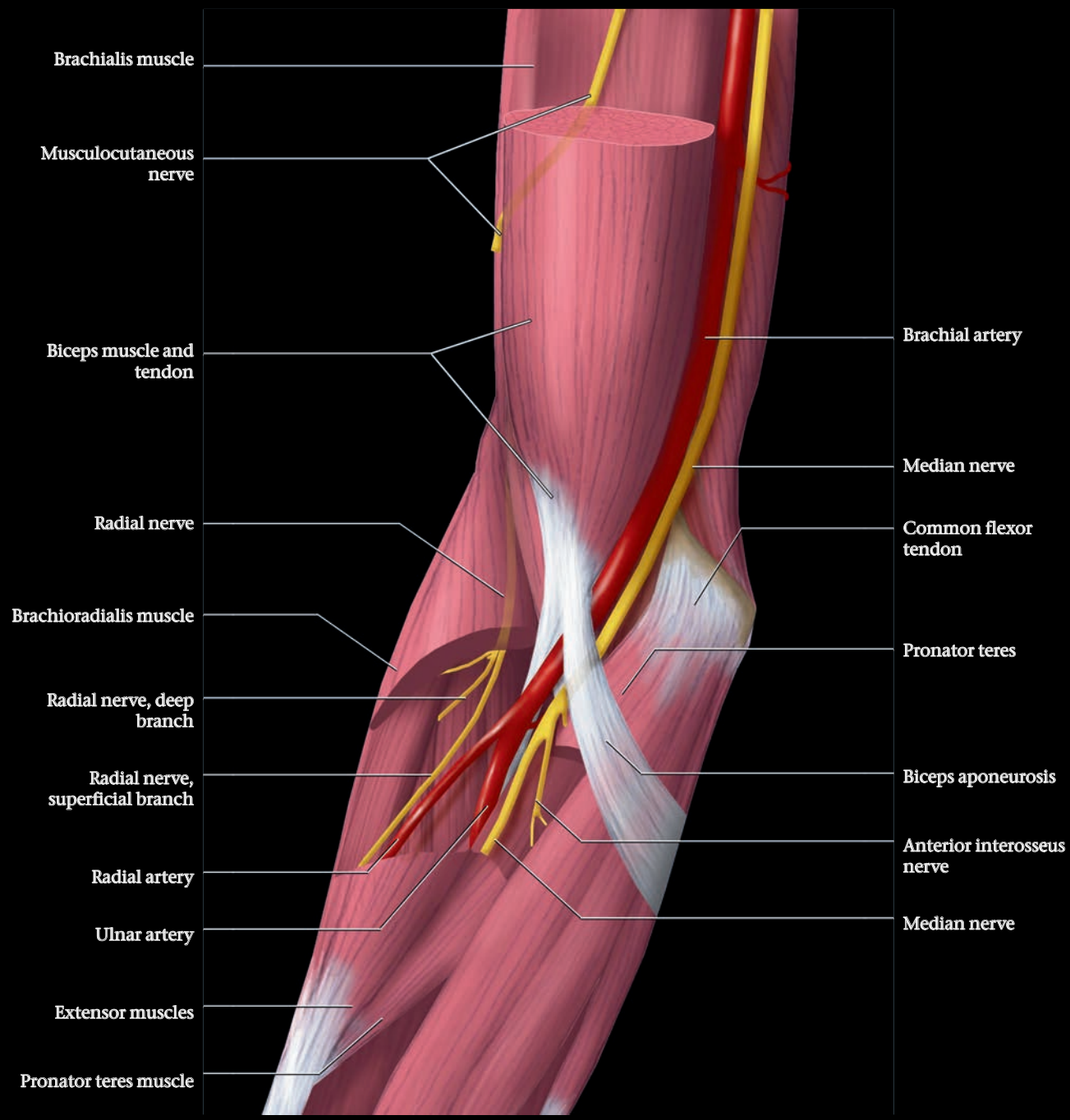
FOREARM

TRANSVERSE US, ANTEROLATERAL FOREARM



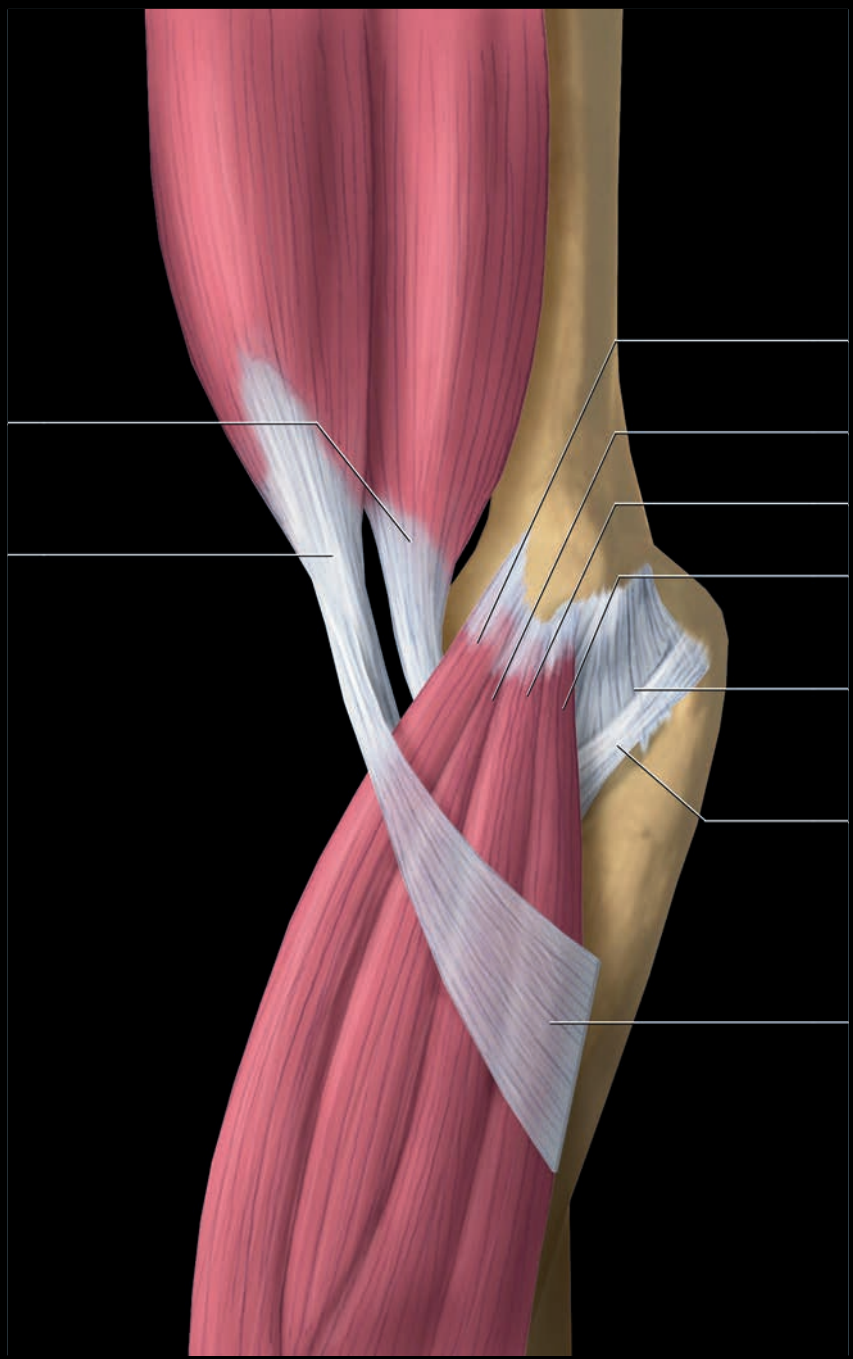
(Top) *Transverse grayscale ultrasound shows the anterolateral proximal 1/3 of the forearm. The anterolateral aspect of the forearm comprises 4 extensor muscles running along the course of the radius.* ***(Middle)*** *Transverse grayscale ultrasound shows the anterolateral aspect of the middle 1/3 of the forearm. The anterolateral group comprises the extensor carpi radialis brevis, the extensor carpi radialis longus, the brachioradialis, and the pronator teres.* ***(Bottom)*** *Transverse grayscale ultrasound shows the anterolateral aspect of the distal 1/3 of the forearm.*

GRAPHIC, ANTERIOR FOREARM



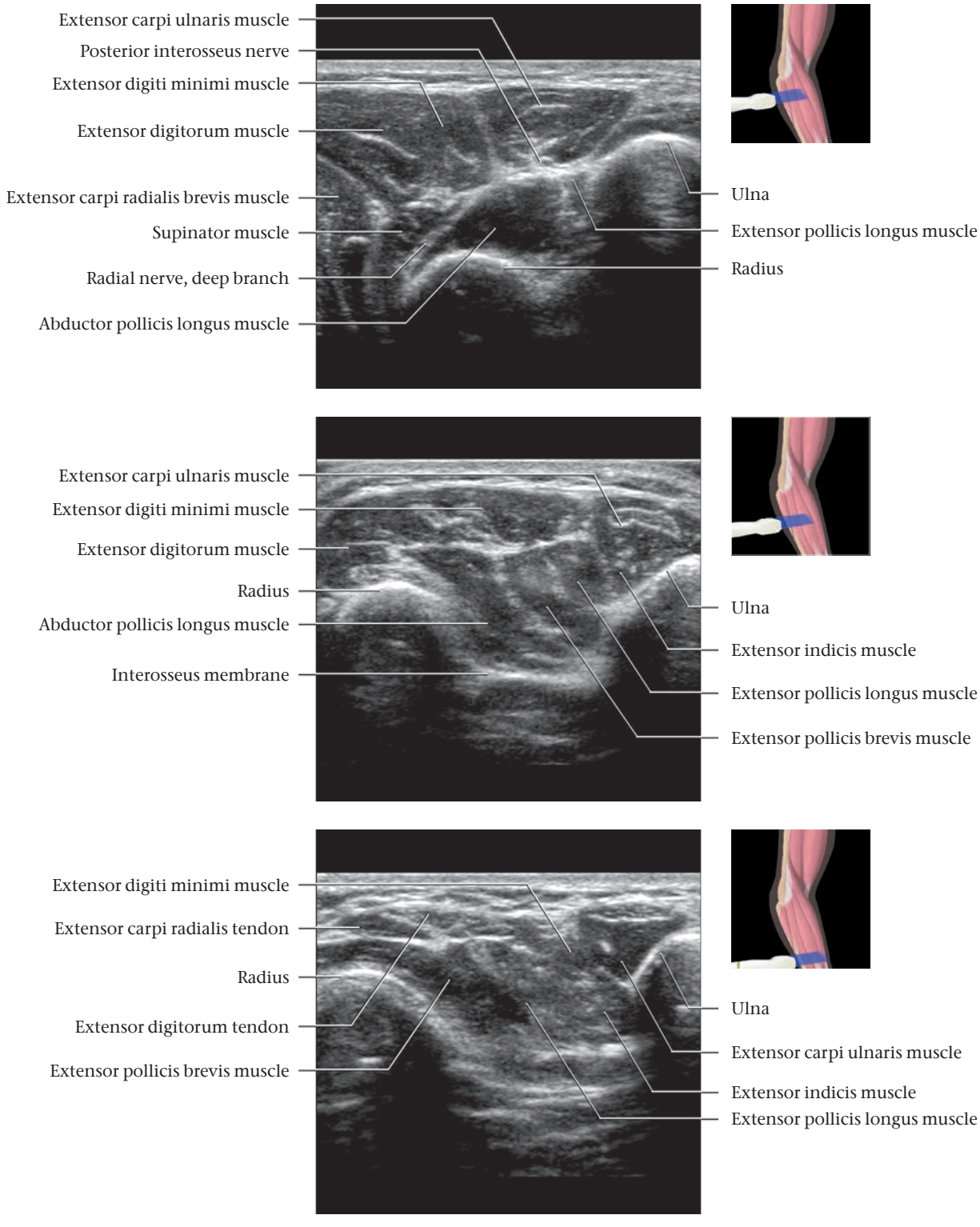
Graphic of the anterior view of the cubital fossa shows the median nerve and brachial artery passing underneath the biceps aponeurosis. The anterior interosseus nerve arises from the median nerve as the median nerve passes between the 2 heads of the pronator teres muscle. The radial nerve, deep to the brachioradialis muscle, is seen dividing into the superficial and deep branches.

GRAPHIC, COMMON FLEXOR TENDON



Graphic of the side view of the medial aspect of the elbow shows the flexor-pronator group and the common flexor tendon origin attaching to the medial epicondyle. The anterior band of the ulnar collateral ligament is deep to the common flexor tendon. The biceps aponeurosis blends with the anterior aspect of the common flexor muscle mass. The flexor digitorum profundus arises from the proximal ulna, posterior and deep to the flexor carpi ulnaris. It does not act on the elbow and is not part of the flexor-pronator group.

TRANSVERSE US, POSTERIOR ASPECT



(Top) *Transverse grayscale ultrasound shows the posterior aspect of the proximal 1/3 of the forearm. The posterior aspect of the forearm contains the extensor muscles. They are contained in 2 groups: Superficial and deep.* ***(Middle)*** *Transverse grayscale ultrasound shows the posterior aspect of the middle 1/3 of the forearm. The superficial group comprises (ulnar to radial) the extensor carpi ulnaris, the extensor digiti minimi, and the extensor digitorum. The deep group comprises the extensor pollicis longus, the extensor pollicis brevis, and the abductor pollicis longus.* ***(Bottom)*** *Transverse grayscale ultrasound shows the posterior aspect of the distal 1/3 of the forearm.*

FOREARM VESSELS

GROSS ANATOMY

Arteries

- Brachial artery
  - Continuation of axillary artery
  - Located in cubital fossa, medial to biceps tendon and deep to biceps aponeurosis
  - Accompanies median nerve
  - Gives off 2 medial branches, which descend toward elbow joint on medial side of brachial artery and contribute to anterior and posterior anastomosis around elbow
  - Brachial artery divides into radial artery and ulnar artery in cubital fossa
- Radial artery
  - Medial to distal biceps tendon
  - Covered by brachioradialis muscle
  - Distally, leaves forearm and moves laterally, crossing floor of anatomical snuffbox
  - Terminates in deep palmar arch of hand
  - Branches
    - Radial recurrent artery: Runs proximally along lateral side of elbow to form anastomosis with branches of deep brachial artery
    - Muscular branches to lateral side of forearm
    - Distal anastomotic branches: Palmar carpal arch, superficial palmar arch, and dorsal carpal arch
- Ulnar artery
  - Proximally deep to pronator teres
  - Distally lies on flexor digitorum profundus and lateral to ulnar nerve
  - Anterior and posterior ulnar recurrent arteries form anastomosis around medial side of elbow with branches of brachial artery
  - Branches
    - Common interosseus artery: Arises in distal aspect of cubital fossa, 2 cm below origin of ulnar artery from brachial artery
    - Anterior interosseus artery: Runs distally on interosseus membrane and ends in dorsal carpal arch; reaches posterior compartment by means of perforating branches; terminates at wrist joint after piercing interosseus membrane; supplies deep muscles of forearm
    - Posterior interosseus artery: Enters posterior compartment proximal to interosseus membrane, between supinator and abductor pollicis longus, and supplies posterior muscles
    - Muscular branches to medial side of forearm
    - Distal anastomotic branches: Palmar carpal arch, dorsal carpal arch

Veins

- Veins of upper limb are variable in number and position
  - In hand there are 2 sets of veins: Deep and superficial
    - Deep veins follow arteries traveling as paired venae comitantes; radial, ulnar, and brachial veins
  - Superficial veins of hand and forearm are drained by cephalic and basilic veins
- Cephalic vein
  - Begins on lateral aspect of wrist by draining blood from venous plexus on dorsum of hand
    - Ascends along lateral side of forearm and upper arm in superficial fascia
    - As vein drains cranially, it receives tributaries from anterior and posterior aspects of forearm
    - Cephalic vein lies laterally in superficial fascia of antecubital fossa and gives off median cubital vein
    - Median vein of forearm flows into medial cubital vein
- Basilic vein
  - Begins on medial side of wrist and drains medial part of venous plexus on dorsum of hand
  - Basilic vein passes upwards on medial side of forearm, receiving anterior and posterior tributaries
  - Passes to anteromedial aspect of elbow where it receives median cubital vein

ANATOMY IMAGING ISSUES

Imaging Recommendations

- Venous examination
  - Examination of upper limb veins is normally performed with patient supine and arm abducted to about 90°
  - Use of high-frequency linear transducer (5-10 MHz) is recommended
    - Determination of compressibility and flow pattern is normally performed
    - Phasicity with respiration noted
  - Augmentation of flow is obtained by manual compression of forearm
  - Alternatively, augmentation can be achieved by asking patient to clench fist
- Arterial examination
  - In patients with possible arterial compression syndromes, arteries are examined in various degrees of abduction so that any compression may be accentuated
  - If angle of insonation is > 60°, Doppler and color sensitivity ↓
  - Keep Doppler gate in center of lumen for peak flow velocity
  - Match color signal scale with flow velocity

Imaging Pitfalls

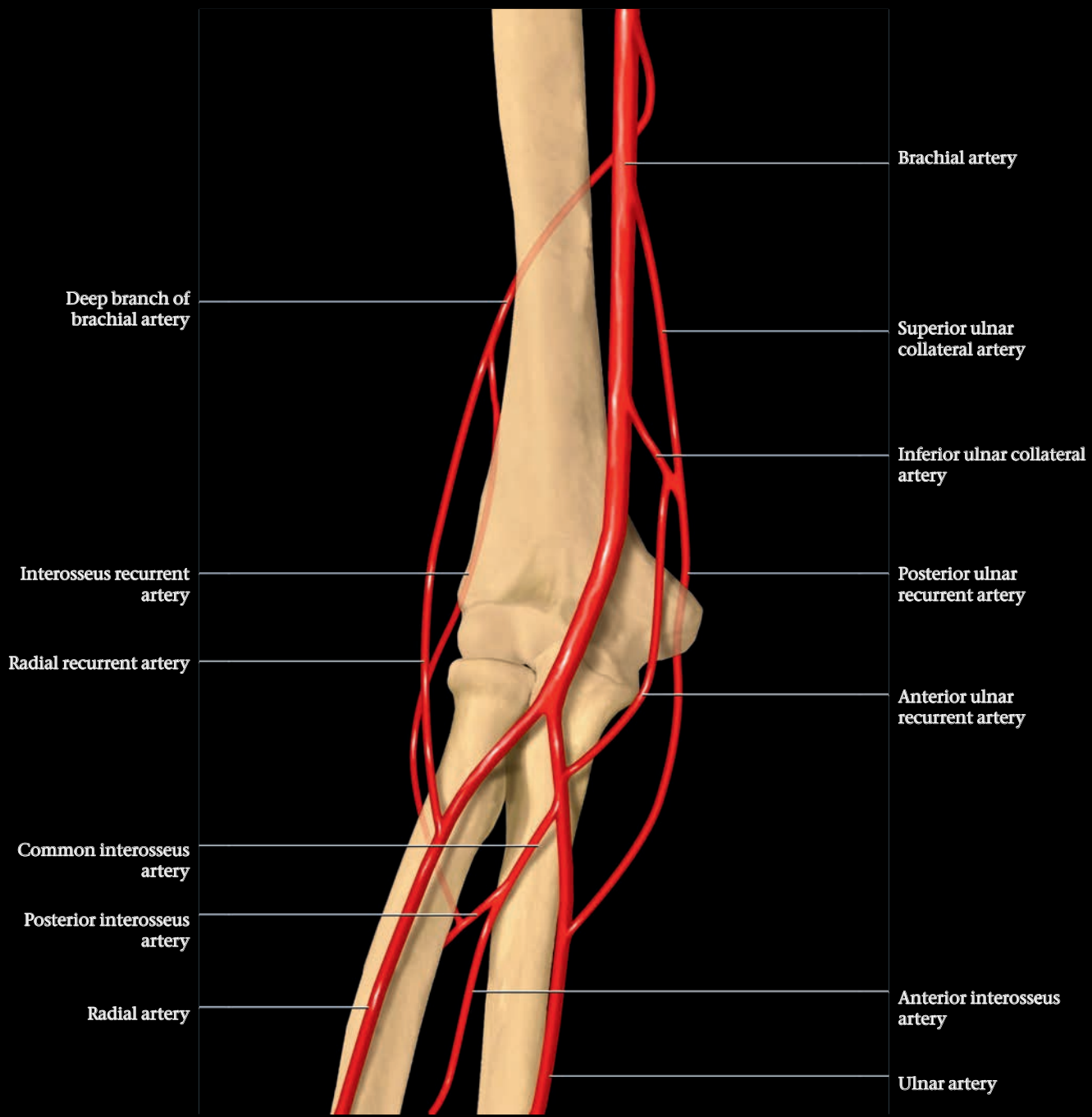
- Gold standard for assessment of accuracy of arterial Doppler ultrasound is usually arteriography

CLINICAL IMPLICATIONS

Clinical Importance

- Brachial artery in antecubital fossa may be used for arterial access for angiography
- High takeoff of radial artery from brachial artery is common anatomical variant
  - On arterial Doppler studies, if either radial or ulnar artery is difficult to trace distally from elbow, then artery should be sought at wrist and followed proximally
- Hemodialysis arteriovenous fistulae are generally constructed by joining the cephalic veins to the radial artery at wrist

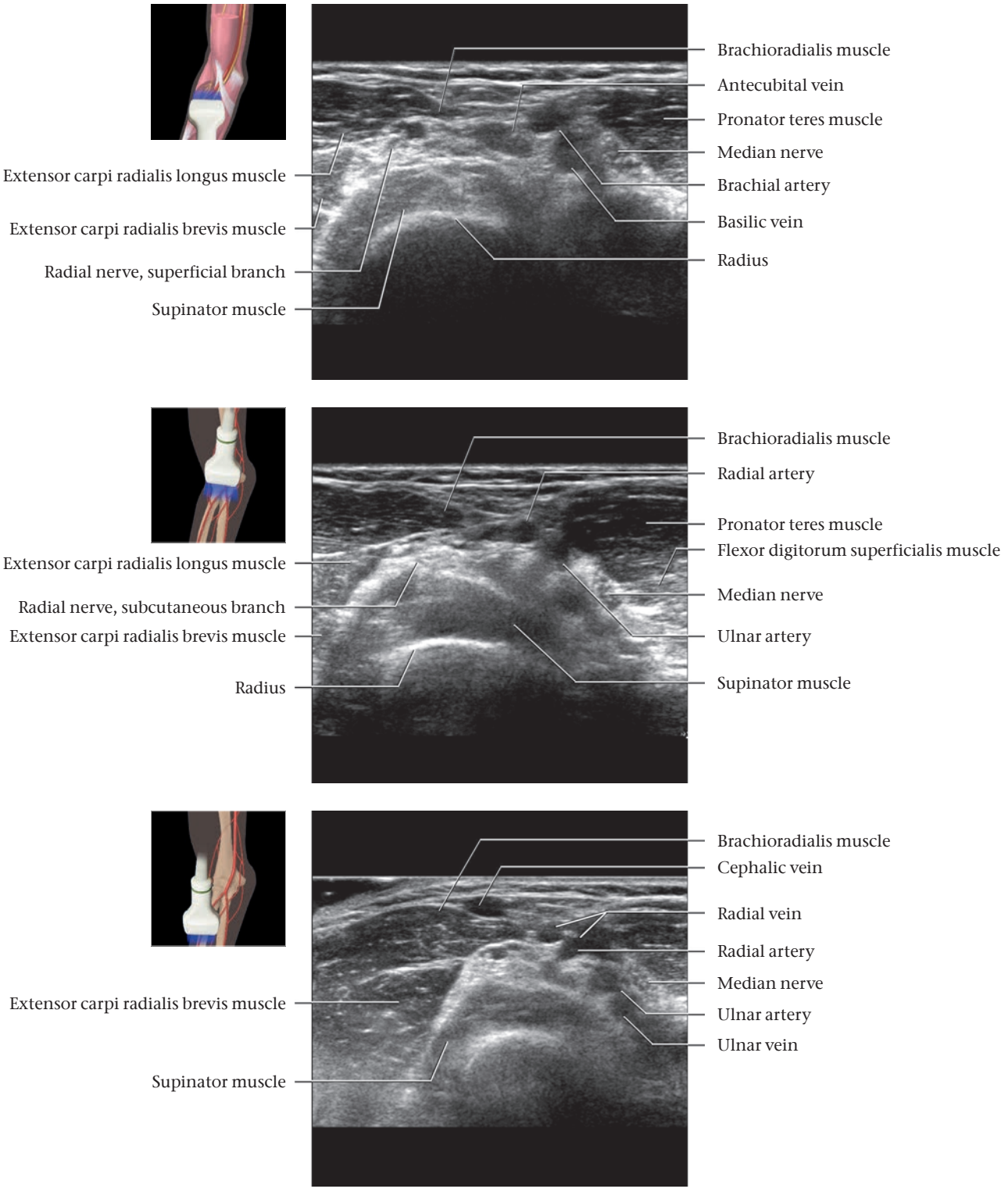
GRAPHIC, FOREARM ARTERIES



Graphic shows the brachial artery, the major artery of the arm. It divides into the radial and ulnar artery in the proximal forearm.

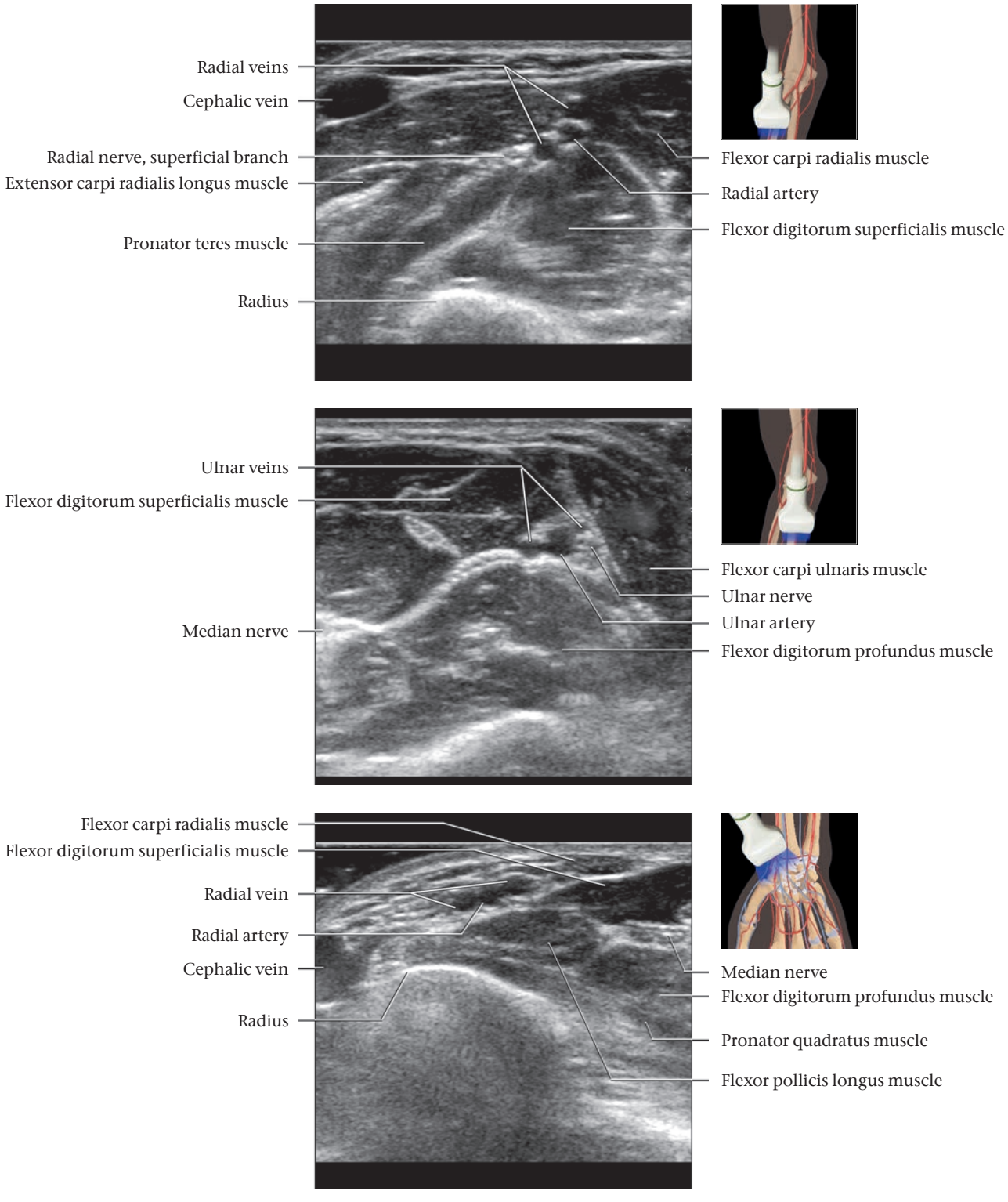
FOREARM VESSELS

TRANSVERSE US, PROXIMAL FOREARM



(Top) *Transverse grayscale ultrasound shows forearm vessels at the volar aspect of the proximal forearm. The brachial artery divides into the radial and ulnar arteries in the proximal arm. The forearm veins are very variable in number and appearance. Both main veins should be assessed when investigating deep vein thrombosis.* ***(Middle)*** *Transverse grayscale ultrasound shows radial vessels on the volar aspect of proximal forearm just distal to bifurcation of the brachial artery.* ***(Bottom)*** *Transverse grayscale ultrasound shows radial vessels on the volar aspect of midforearm. The superficial branch of the radial nerve roughly follows the radial artery while the ulnar nerve closely follows the ulnar artery.*

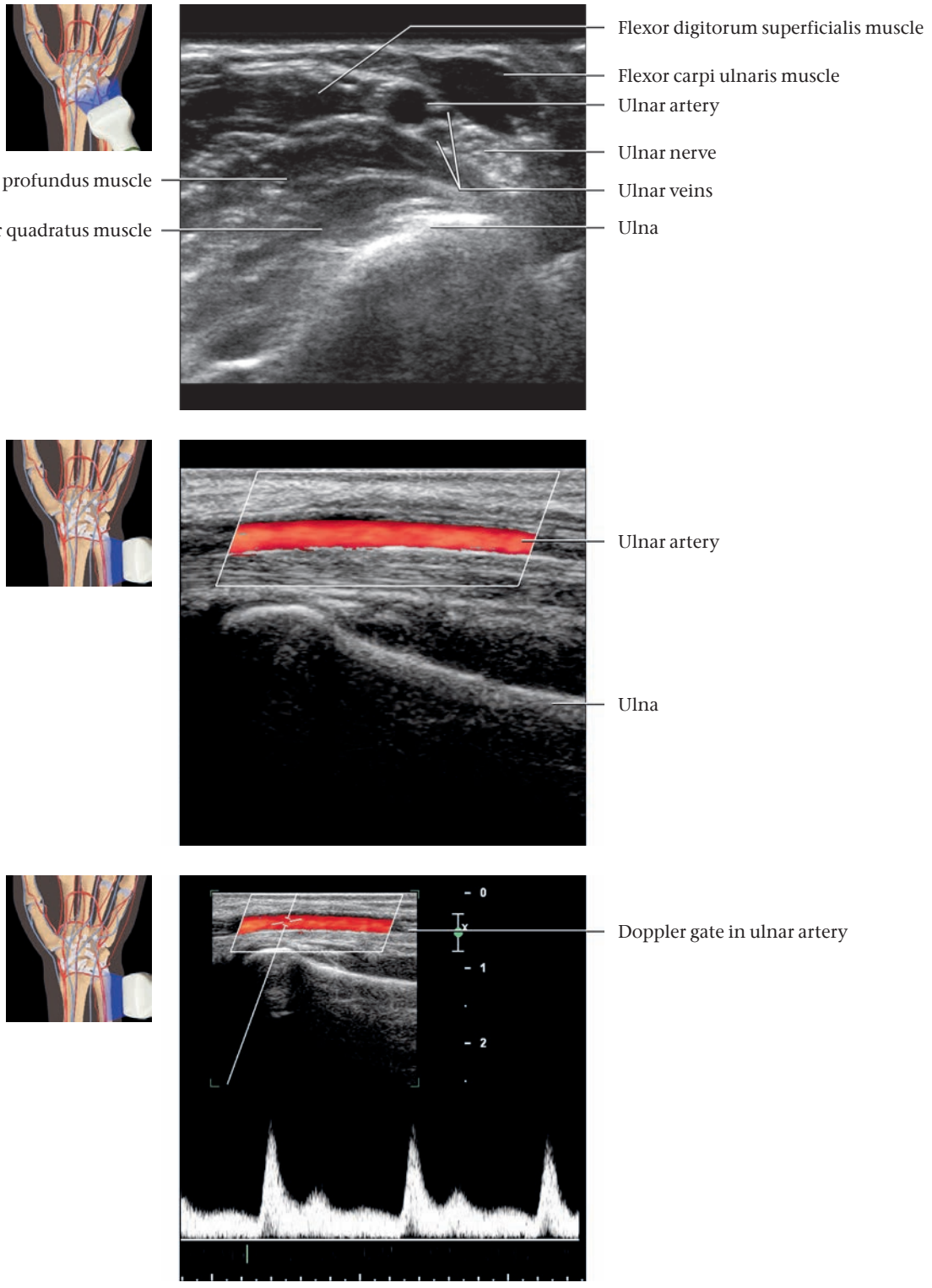
TRANSVERSE US, RADIAL ARTERY



(Top) *Transverse grayscale ultrasound shows the radial artery on the volar aspect of the midforearm. The radial artery serves as a landmark to divide the anterior (flexor) and posterior (extensor) compartments of the forearm.* ***(Middle)*** *Transverse grayscale ultrasound shows the ulnar artery on the volar aspect of the midforearm. The ulnar artery is more variable in position than the radial artery. It may arise more proximal in the arm region. When the ulnar artery arises proximally, it often has an aberrant course and may lie superficial to the flexor muscles in the forearm.* ***(Bottom)*** *Transverse grayscale ultrasound shows the radial artery on the volar aspect of distal forearm. The radial artery is sometimes used instead of the long saphenous vein in coronary artery surgery. The caliber of the artery can be checked prior to surgery by ultrasound.*

FOREARM VESSELS

TRANSVERSE & LONGITUDINAL US, ULNAR ARTERY



(Top) *Transverse grayscale ultrasound shows the ulnar artery on the volar aspect of the distal forearm. The Allen test is performed clinically to check dual arterial supply to the hand prior to radial artery cannulation or excision.* ***(Middle)*** *Longitudinal color Doppler ultrasound shows the ulnar artery on the volar aspect of distal forearm. Flow velocity and direction is denoted by the color signal. The normal diameter of the ulnar artery (1.9-2.2 mm) is measured near the wrist.* ***(Bottom)*** *Longitudinal spectral Doppler analysis of the ulnar artery on the volar aspect of the distal forearm is shown. The spectral gate is placed in the middle of the arterial lumen. Normal unidirectional flow is present with a systolic peak and good diastolic flow. The peak systolic velocity (PSV) of the ulnar artery ranges between 40-90 cm/s while end-diastolic velocity ranges between 5-12 cm/s. Pulsatility index (PI) is variable, ranging 3.9-5.0.*

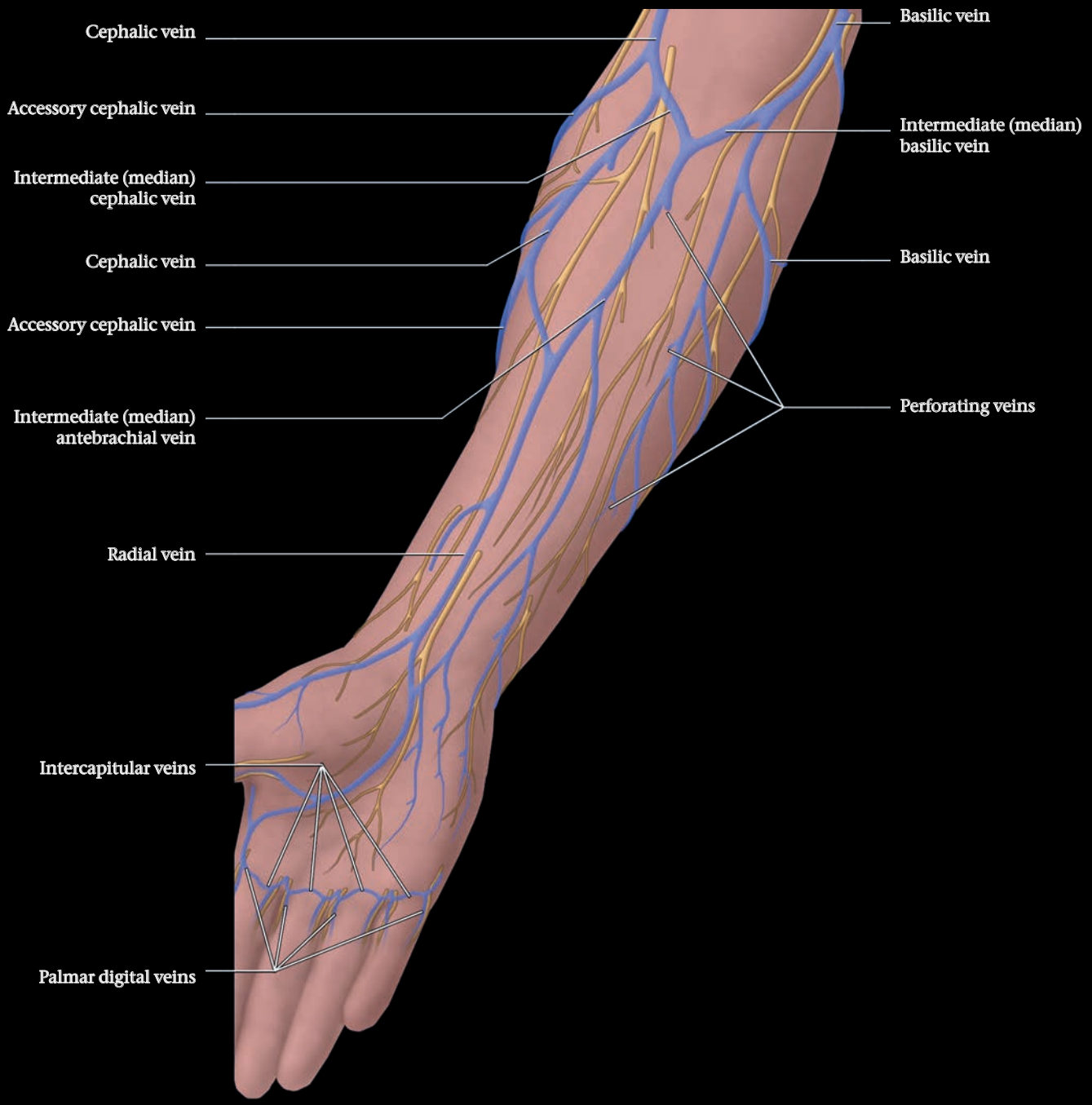
ARTERIES AT DISTAL FOREARM AND HAND



(Top) *Longitudinal color Doppler ultrasound shows the radial artery on the volar aspect of the distal forearm just proximal to the wrist. The normal diameter of the radial artery just proximal to the wrist ranges 2.2-2.8 mm.* ***(Middle)*** *Spectral analysis shows the radial artery just proximal to the wrist. Spectral analysis is best performed with the artery visualized longitudinally rather then transversely. The normal angle corrected peak systolic velocity (PSV) of the radial artery ranges 40-90 cm/s, the end diastolic velocity ranges 5-10 cm/s, and pulsatility index (PI) is variable, ranging 3.9-5.0.* ***(Bottom)*** *Graphic shows the distal aspect of the radial and ulnar artery in the forearm and their terminal course in the wrist and hand to form the superficial and deep palmar arterial arches.*

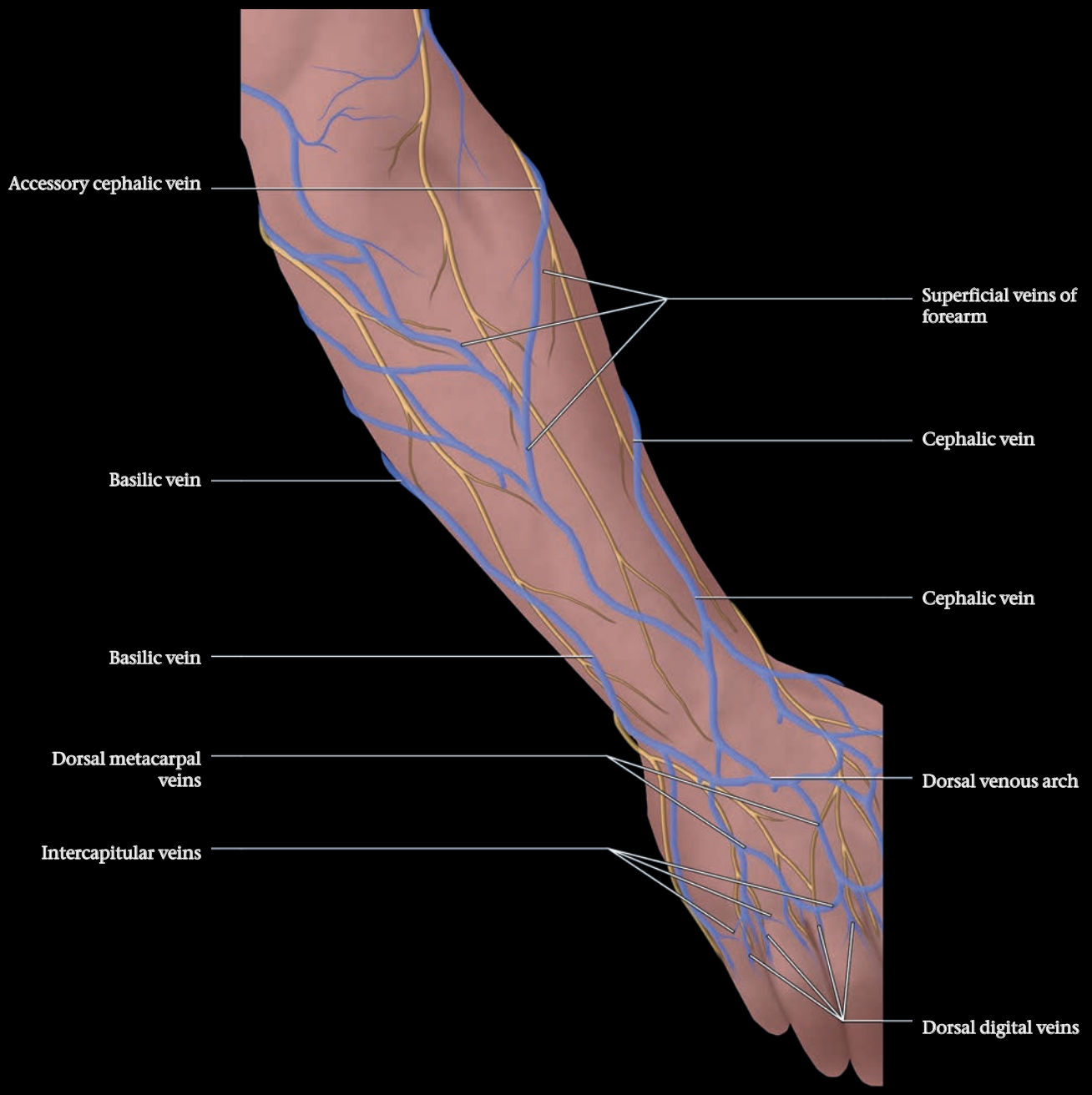
FOREARM VESSELS

GRAPHIC, VENOUS SYSTEM



Graphic shows the superficial venous system of the forearm. The most important collecting vein of the forearm and arm is the cephalic vein. The cephalic vein proceeds from the radial margin of the dorsal venous network of the hand and follows a course diagonally above the radial margin of the forearm to the cubital fossa. From there, it continues laterally in the distal arm, moving anteromedially in the upper arm to enter the axillary vein just below the clavicle. It contains 6-10 valves. The ulnar and radial veins collect blood from the deep palmar arch and course in pairs alongside the corresponding arteries. Blood is continuously shunted from these superficial veins in the subcutaneous tissue to deep veins via the perforating veins. Although the upper extremities have many communicating veins, they have no clinical significance and are therefore not specifically named and located.

GRAPHIC, VENOUS SYSTEM



Graphic shows the posterior view of the superficial venous system of the forearm. The basilic vein starts from the ulnar margin of the dorsal venous plexus and travels onwards to the bend of the elbow, where it is joined by the cephalic vein. It contains 4-8 valves. There are 2 additional small branches that pass superficially on the volar side of the forearm, the median antebrachial vein and the median cubital vein, which flow into the cephalic vein and the basilic vein somewhat above the bend of the elbow. Although the upper extremities has many communicating veins, they have no clinical significance and are therefore not specifically named and located.

WRIST

TERMINOLOGY

Definitions

- Articulation complex comprising distal radioulnar, radiocarpal, ulnocarpal, pisotriquetral, midcarpal, and carpometacarpal joints

IMAGING ANATOMY

Osseous Structures

- Distal radius: Lister tubercle on dorsal surface
- Distal ulna: Ulnar variance refers to length of ulnar head relative to distal radius: Ulnar minus or ulnar plus
- Proximal carpal row: Scaphoid, lunate, triquetrum, pisiform
  - Scaphoid: Proximal and distal pole separated by waist
    - Tuberosity = volar prominence of distal pole
  - Lunate: Half-moon-shaped
  - Triquetrum: Triangular-shaped
  - Pisiform: Pea-shaped sesamoid-type bone to which flexor carpi ulnaris attaches and continues distally as pisohamate and pisometacarpal ligaments
- Distal carpal row: Trapezium, trapezoid, capitate, hamate
  - Trapezium: Saddle-shaped bone linking carpus and thumb
  - Trapezoid: Wedge-shaped bone
  - Capitate: Head (proximal), neck (midportion), and body (bulky distal portion)
  - Hamate: Hook (hamulus) arises from palmar surface

Ligaments

- Extrinsic (on palmar or volar aspects of wrist) or intrinsic (between carpal bones)
- Major wrist stabilizers: Volar ligaments
- Extrinsic ligaments
  - Palmar: Radioscaphocapitate, radiolunotriquetral, radioscapholunate, ulnotriquetral, ulnolunate, scaphotriquetral
  - Dorsal: Scaphotriquetral, radiotriquetral, ulnotriquetral, radial collateral
- Intrinsic ligaments
  - Proximal interosseous: Scapholunate, lunotriquetral
  - Distal interosseous: Trapeziotrapezoid, trapeziocapitate, capitohamate

Muscles and Tendons

- **Flexors, deep**
  - Flexor digitorum profundus: Originated from ulna; inserted to index, middle, ring, and little finger distal phalangeal bases
  - Flexor pollicis longus: Originated from radius, interosseous membrane and coronoid process of ulna; inserted to distal phalangeal base of thumb
- **Flexors, superficial**
  - Flexor carpi radialis: Originated from medial epicondyle; inserted to 2nd metacarpal base
  - Palmaris longus: Originated from medial epicondyle; inserted to palmar aponeurosis
  - Flexor carpi ulnaris: Originated from medial epicondyle and medial olecranon/proximal ulna; inserted to pisiform
  - Flexor digitorum superficialis: Originated from medial epicondyle and coronoid process of ulna and anterior radius; inserted to middle phalangeal bases of digits 2-5
- **Extensors, deep**
  - Abductor pollicis longus: Originated from ulna; inserted to radial aspect 1st metacarpal base
  - Extensor pollicis brevis: Originated from radius; inserted to proximal phalangeal base of thumb
  - Extensor pollicis longus: Originated from midulna; inserted to distal phalangeal base of thumb
  - Extensor indicis: Originated from midulna; joins ulnar side of extensor digitorum tendon inserting into 2nd digit extensor hood
- **Extensors, superficial**
  - Extensor carpi radialis longus: Originated from lateral supracondylar ridge of humerus; inserted to dorsal radial 2nd metacarpal base
  - Extensor carpi radialis brevis: Originated from lateral humeral epicondyle; inserted to dorsal radial 3rd metacarpal base
  - Extensor digitorum: Originated from lateral humeral epicondyle; inserted to distal phalangeal bases of digits of 2-5
  - Extensor digiti minimi: Originated from lateral humeral epicondyle; inserted to extensor hood of little finger
  - Extensor carpi ulnaris: Originated from lateral humeral epicondyle; inserted to 5th metacarpal base

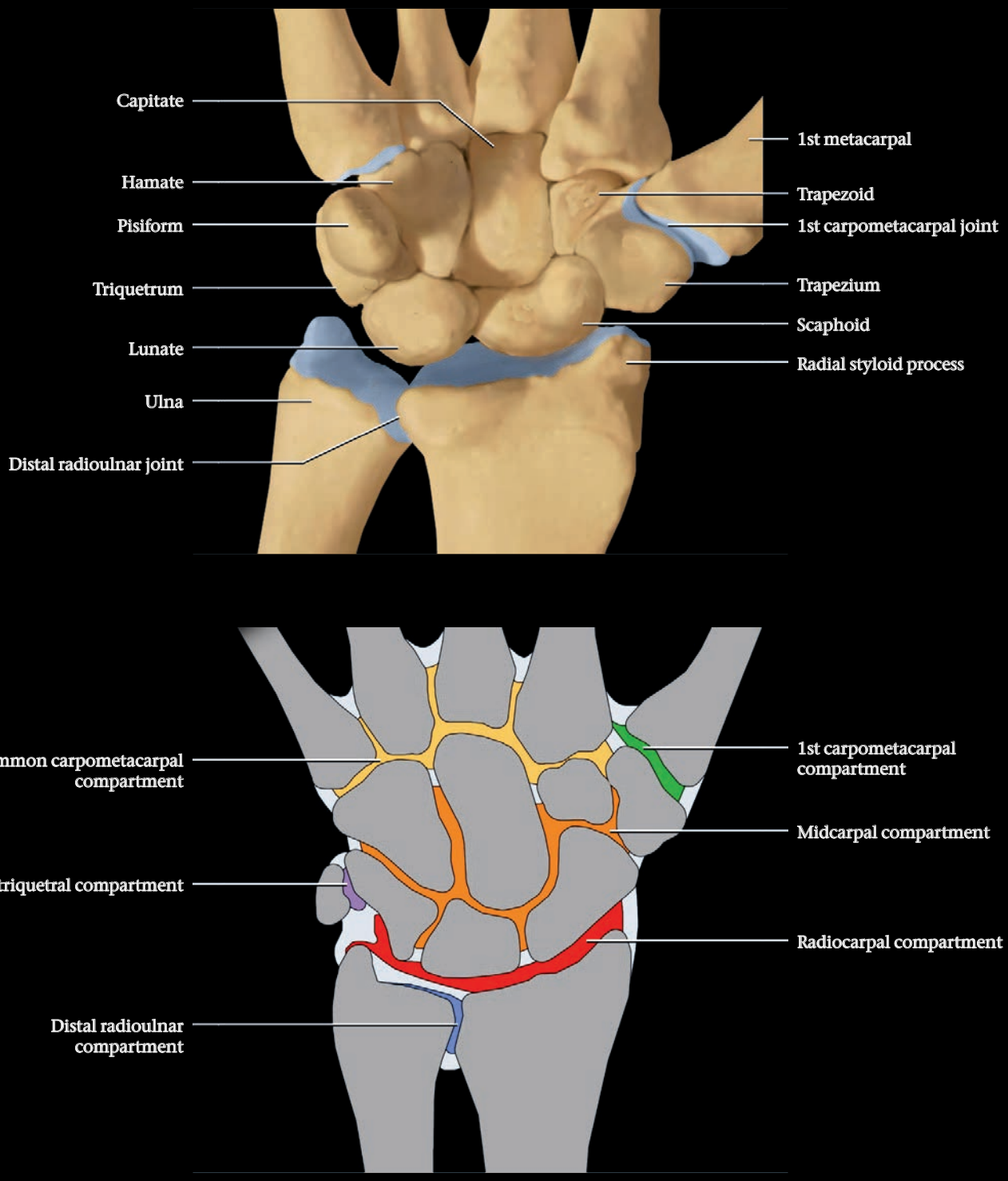
Retinacula

- **Flexor retinaculum**
  - Also called transverse carpal ligament: Attached to pisiform and hook of hamate, scaphoid, and trapezium
- **Extensor retinaculum**
  - Attaches to ulnar styloid process, triquetrum, and pisiform medially; crosses obliquely to attach to Lister tubercle and radial styloid process laterally
    - Sends septa to radius, creating 6 compartments for extensor tendons
  - Compartment contents
    - 1st: Abductor pollicis longus (APL) and extensor pollicis brevis (EPB)
    - 2nd: Extensor carpi radialis, longus (ECRL) and brevis (ECRB)
    - 3rd: Extensor pollicis longus (EPL)
    - 4th: Extensor digitorum (ED) and extensor indicis (EI)
    - 5th: Extensor digiti minimi (EDM)
    - 6th: Extensor carpi ulnaris (ECU)

Anatomic Spaces

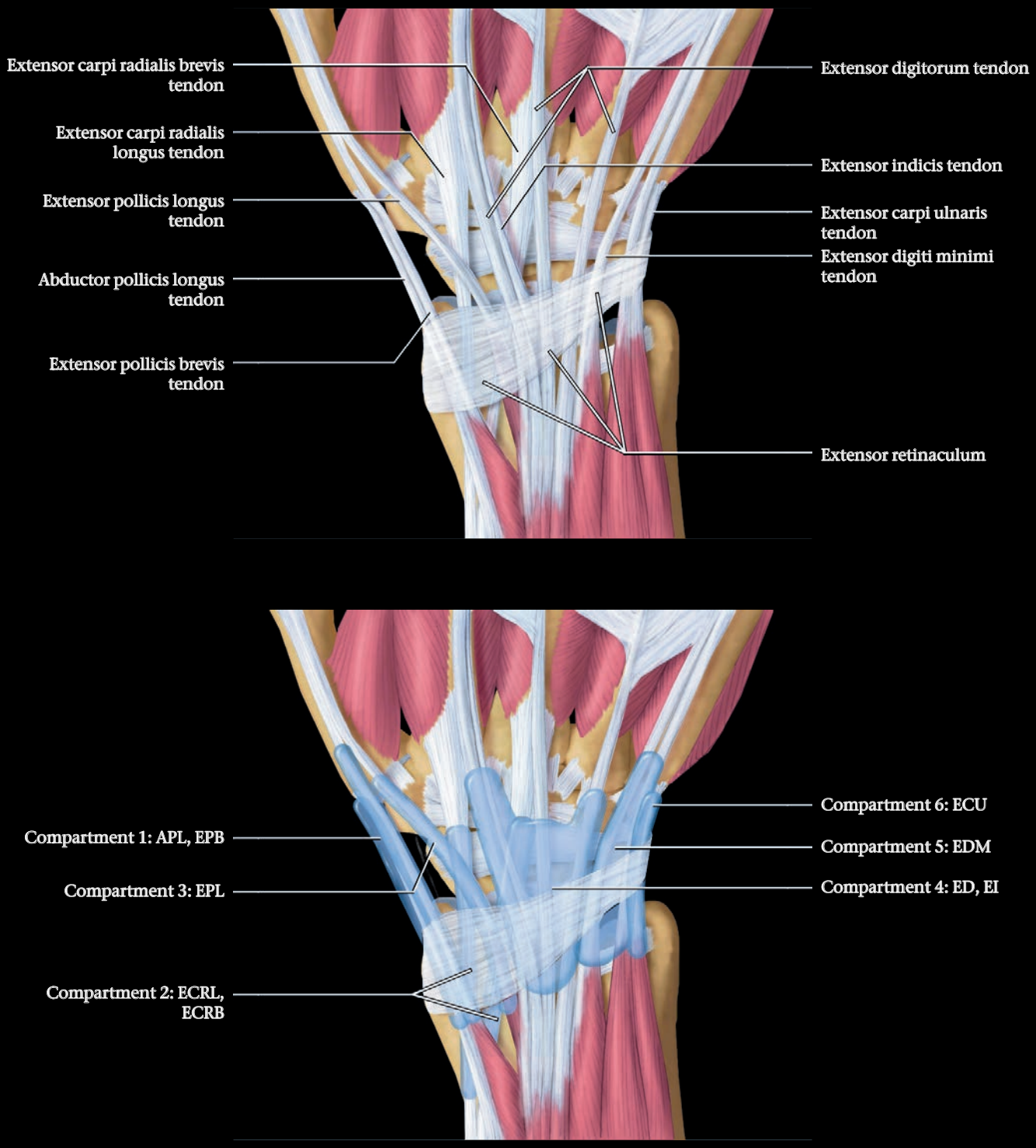
- **Carpal tunnel**
  - Margins: Carpal bones (dorsal margin); flexor retinaculum (volar margin); pisiform and hook of hamate (ulnar margin); scaphoid and trapezium (radial margin); radiocarpal joint (proximal margin); and metacarpal base (distal margin)
    - Contents: Flexor digitorum superficialis, flexor digitorum profundus, flexor pollicis longus, median nerve
- **Guyon canal**
  - Margins: Fascial extension from flexor retinaculum, volar carpal ligament (volar margin), pisiform and flexor carpi ulnaris (ulnar margin), flexor retinaculum (radial and dorsal margins)
    - Contents: Ulnar artery and vein, ulnar nerve

GRAPHICS, CARPAL BONES AND WRIST COMPARTMENTS



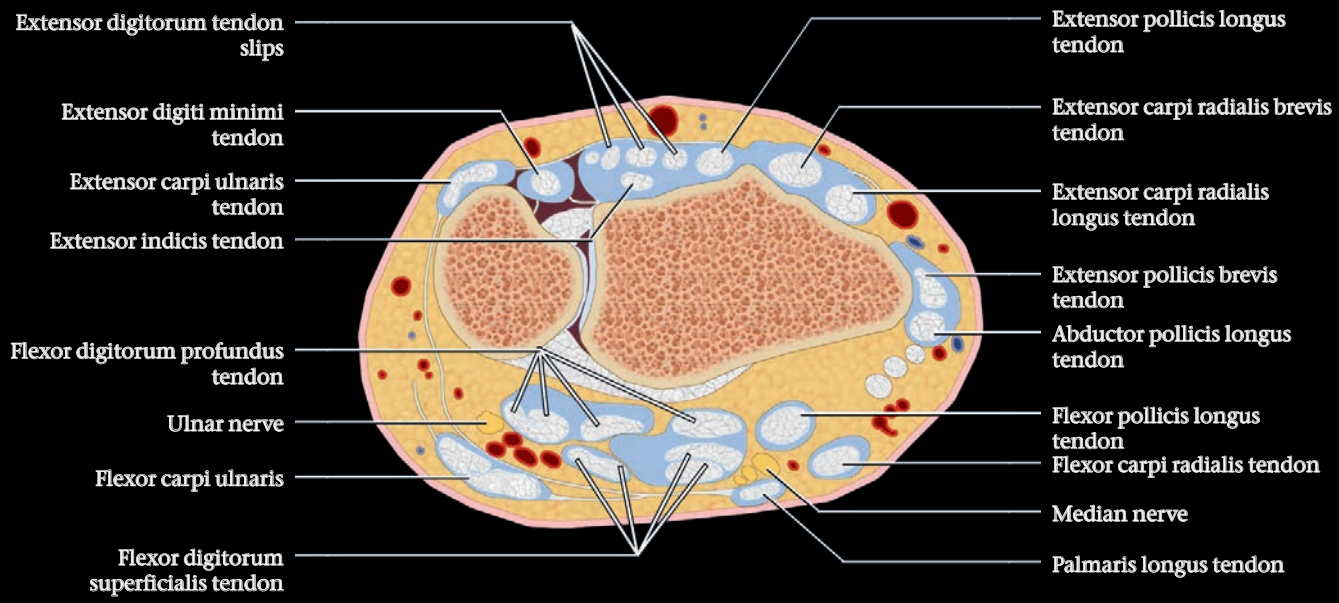
(Top) *Graphic shows the bones of the wrist joint.* ***(Bottom)*** *Graphic shows the 5 different wrist compartments: Distal radioulnar compartment is separated from the radiocarpal compartment by the triangular fibrocartilage complex (TFCC). Pisotriquetral compartment is separated from the radiocarpal compartment in 20%. Midcarpal compartment is separated from the radiocarpal compartment by the scapholunate and lunotriquetral ligaments and typically communicates with the carpometacarpal joints. First carpometacarpal compartment is separated from the common carpometacarpal compartment by the trapeziometacarpal ligament.*

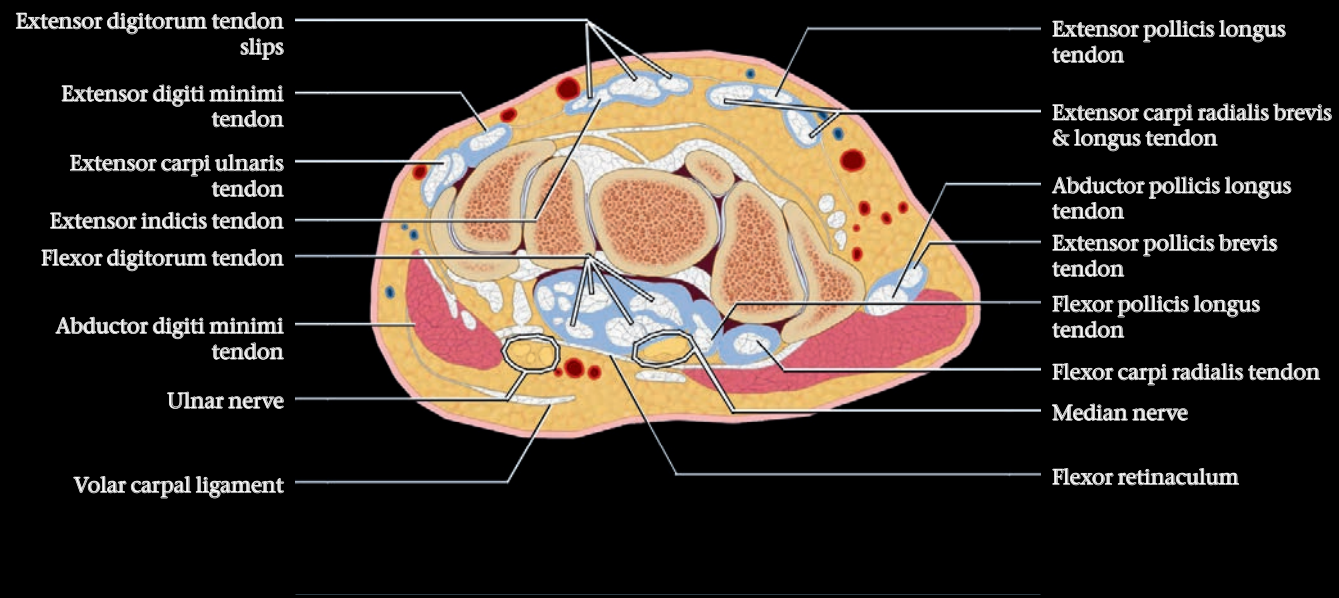
GRAPHICS, DORSAL TENDONS AND TENDON SHEATHS



*(**Top**) Dorsal extensor tendons pass deep to the extensor retinaculum, separated into 6 compartments by fibrous attachments of the retinaculum to underlying bone. Compartment contents include abductor pollicis longus (APL) and extensor pollicis brevis (EPB), extensor carpi radialis longus (ECRL) and brevis (ECRB), extensor pollicis longus (EPL), extensor digitorum (ED) and extensor indicis (EI), extensor digiti minimi (EDM), and extensor carpi ulnaris (ECU). **(Bottom)** Separate tendon sheaths enclose dorsal extensor tendons in compartments 1-6 individually.*

GRAPHICS, TENDONS: RELATIONS TO DORSAL & VOLAR WRIST

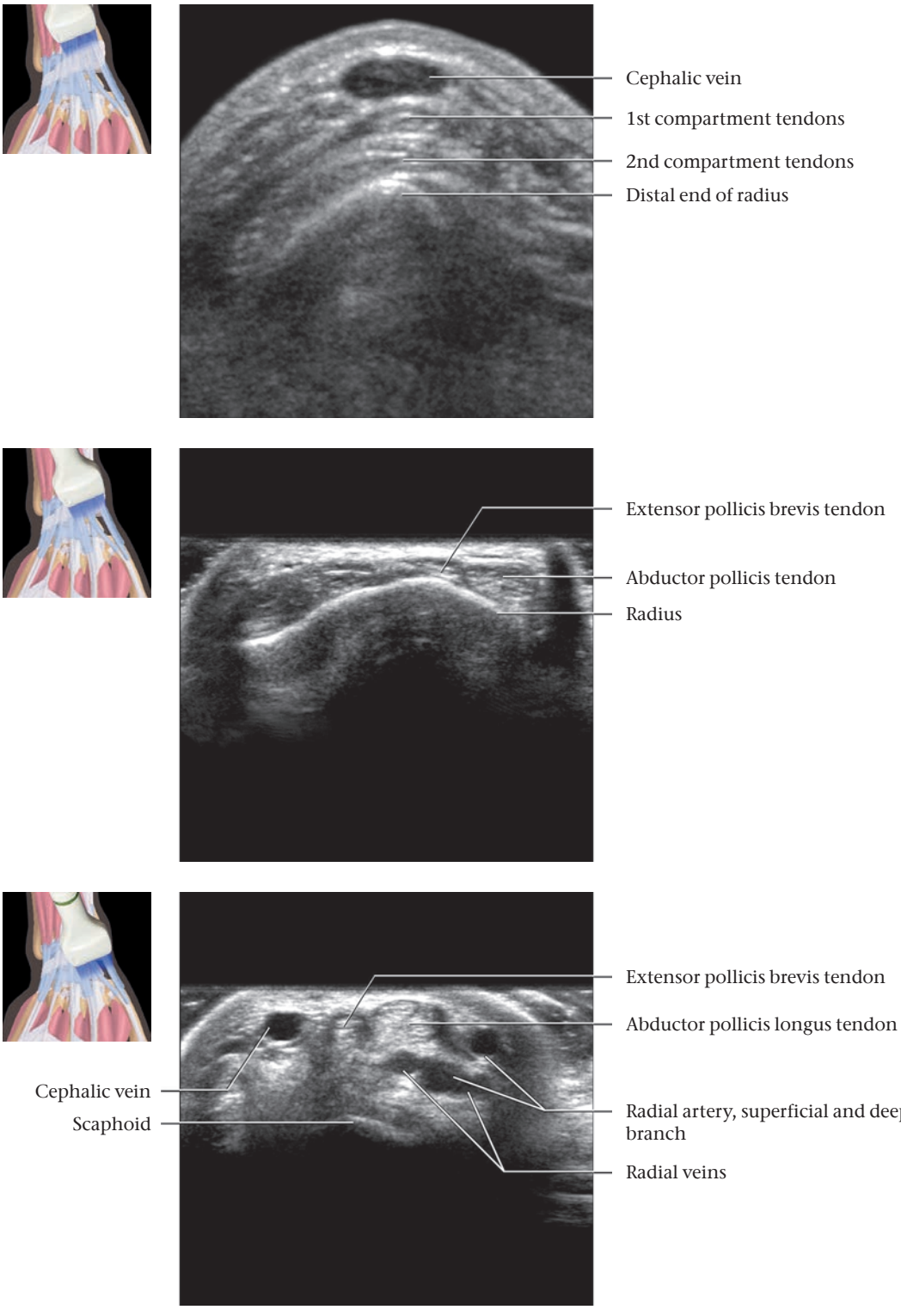




(Top) *Graphic representation shows tendons in the proximal wrist. Extensor tendons are deep to the extensor retinaculum, whereas flexor tendons are proximal to the flexor retinaculum at this level in the wrist.* ***(Bottom)*** *Midcarpal tunnel is shown. Median nerve is slightly flattened as it passes deep to the flexor retinaculum and remains superficial to the flexor pollicis longus. Ulnar nerve, artery, and veins lie lateral to the pisiform and may divide near the pisiform into deep and superficial branches.*

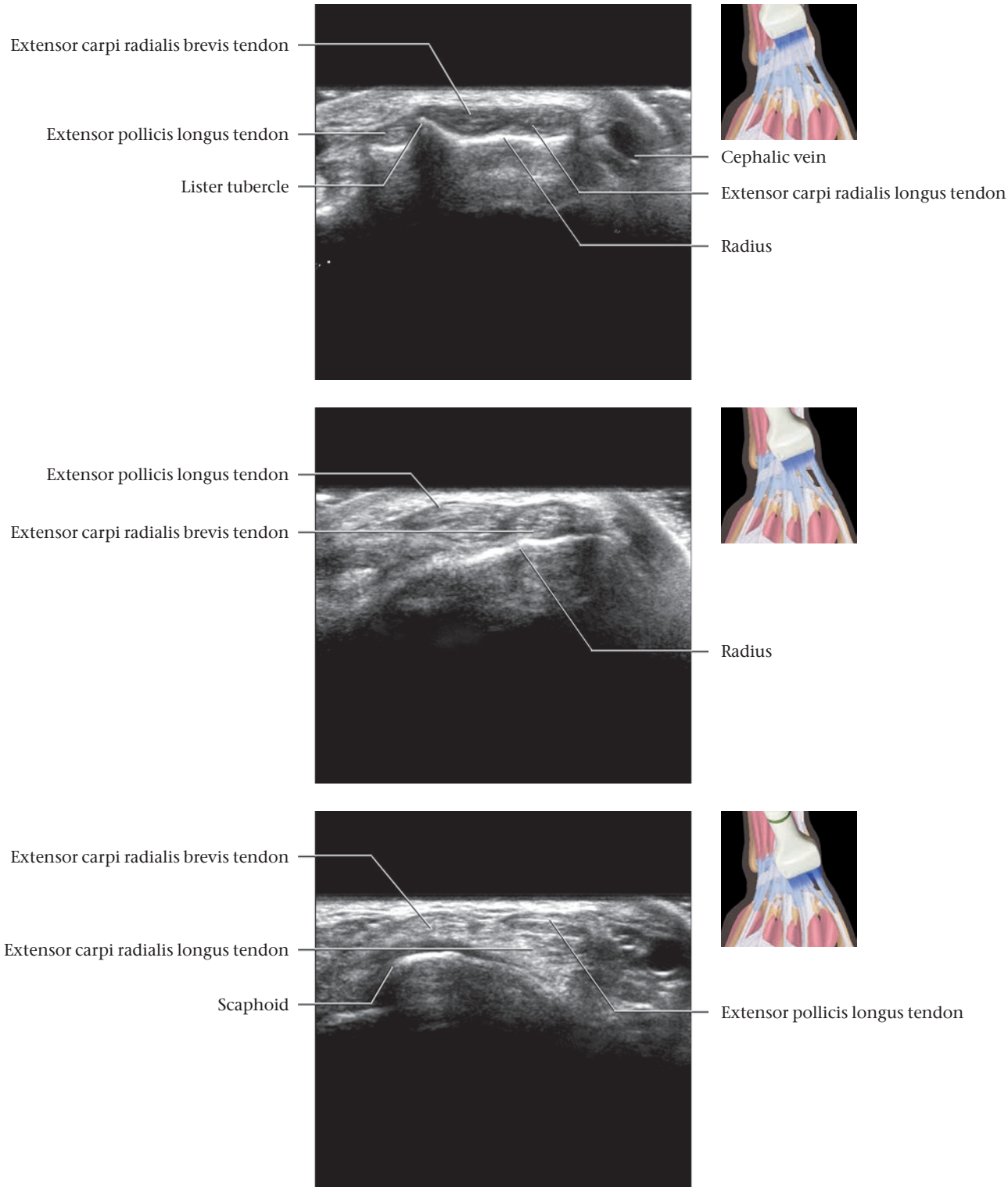
WRIST

TRANSVERSE US, RADIAL ASPECT



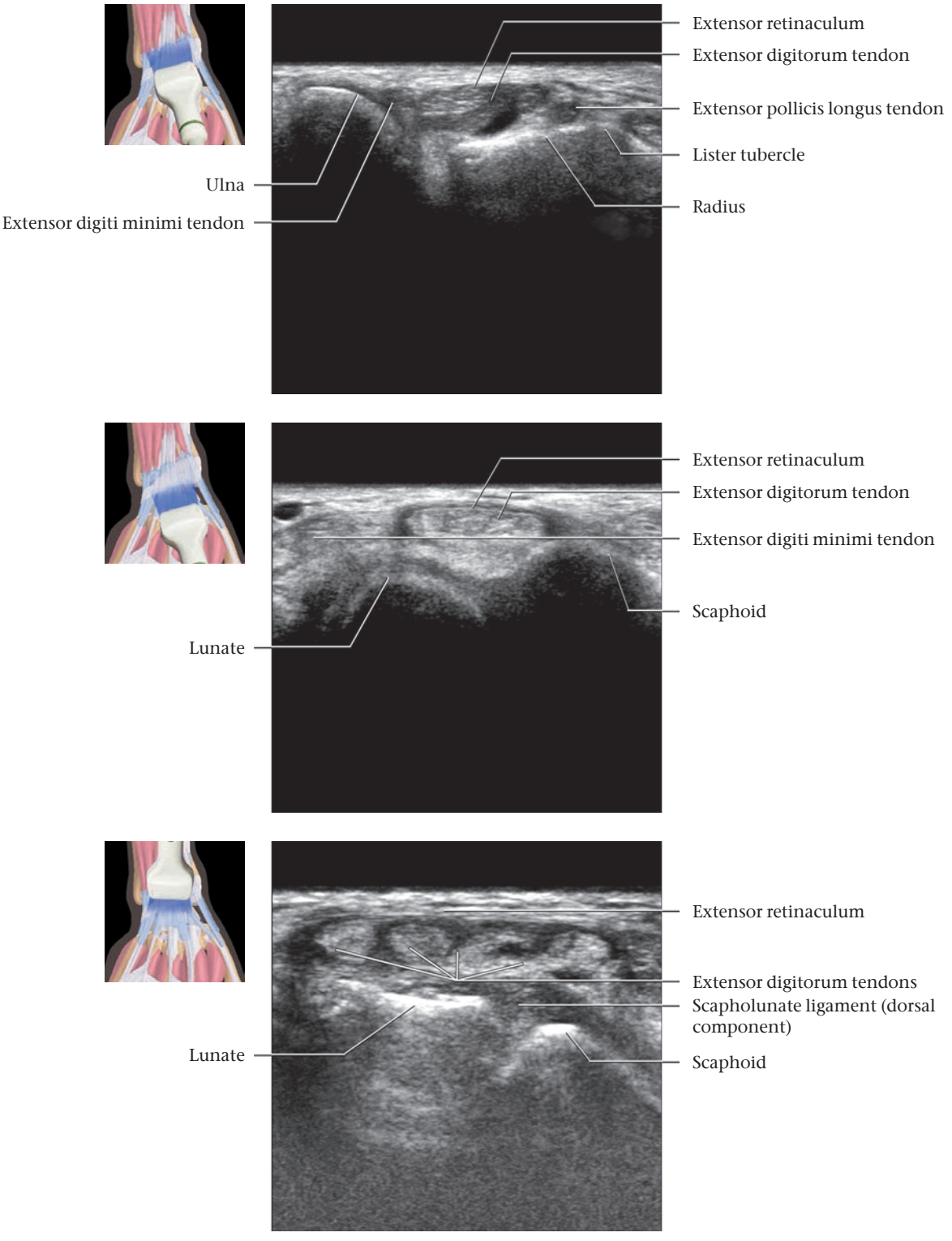
(Top) *Transverse grayscale US shows the 1st extensor compartment proximal to the distal radius. The 1st compartment contains the extensor pollicis brevis (EPB) and the larger abductor pollicis longus (APL) tendons. The 1st compartment tendons run obliquely over 2nd compartment tendons a few centimeters proximal to the wrist. Pain may occur at this intersection (intersection syndrome).* ***(Middle)*** *Transverse grayscale US shows the 1st extensor compartment at the distal radius. EPB extends to the base of the proximal phalanx of the thumb, whereas APL inserts onto the base of the 1st metacarpal bone. They form the radial aspect of the anatomical snuff box. These tendons are swollen in patients with de Quervain disease.* ***(Bottom)*** *Transverse grayscale US shows the 1st extensor compartment at the level of the scaphoid. Dorsal branch of the radial artery passes deep to the tendons of the 1st extensor compartment to enter the dorsum of the hand.*

TRANSVERSE US, DORSAL WRIST



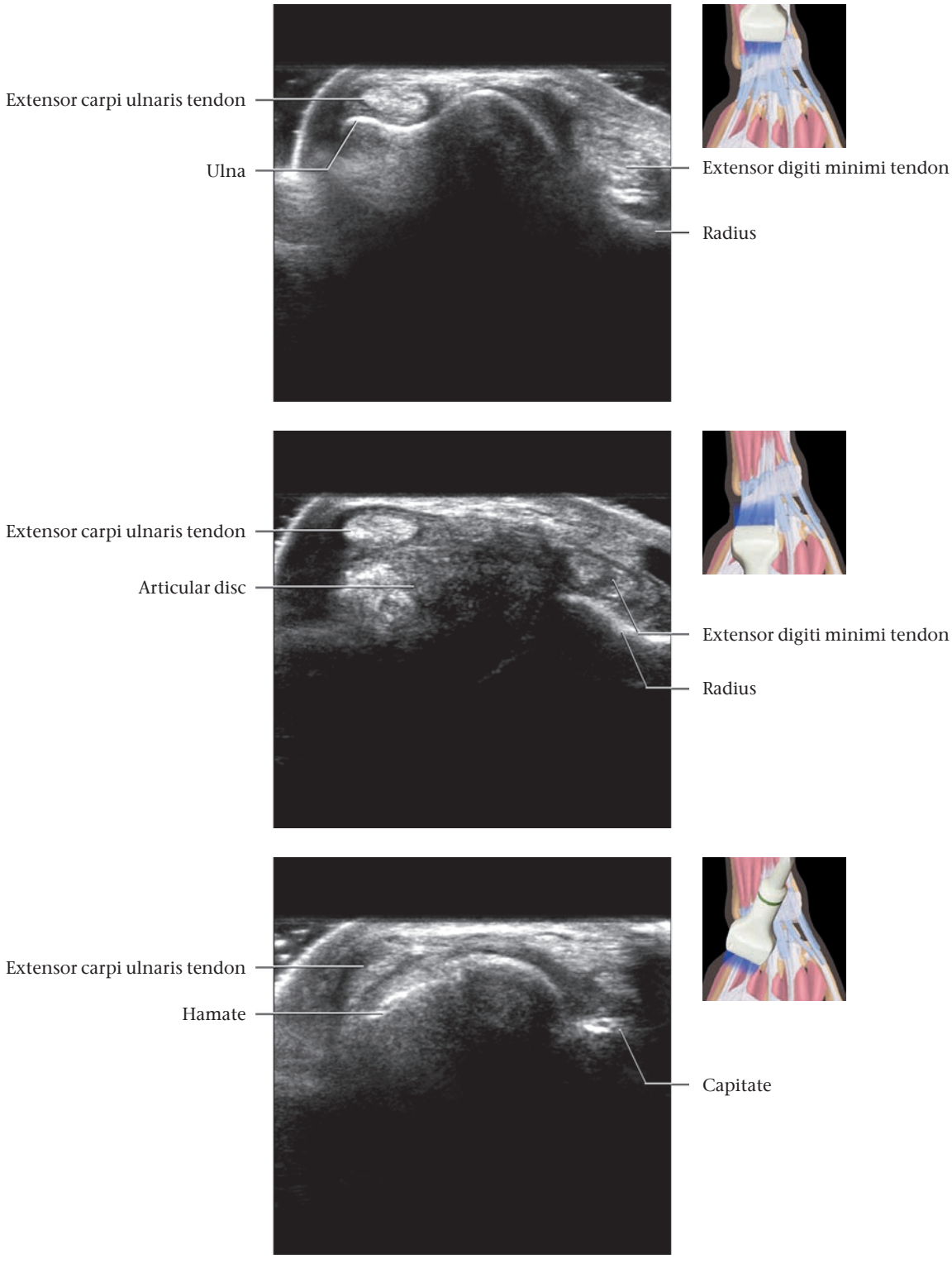
(Top) *Transverse grayscale US shows the 2nd & 3rd extensor compartments at the distal radius level. The 2nd extensor compartment comprises the extensor carpi radialis longus (ECRL) and extensor carpi radialis brevis (ECRB). ECRL inserts into the base of the index finger metacarpal, whereas ECRB inserts into the middle finger metacarpal. The 2nd compartment is separated from the 3rd compartment, containing the extensor pollicis longus (EPL), by the Lister tubercle.* ***(Middle)*** *Transverse grayscale US shows the 2nd and 3rd extensor compartments at the distal radius level. The 2nd compartment forms the dorsal aspect of the anatomical snuff box.* ***(Bottom)*** *Transverse grayscale US shows the 2nd extensor compartment at the scaphoid level. The EPL tendon hooks around the Lister tubercle and crosses superficial to the 1st compartment tendons as it runs toward its insertion on the base of the distal phalanx of the thumb. It is prone to rupture in inflammatory arthropathies and distal radial fractures.*

TRANSVERSE US, EXTENSOR DIGITORUM



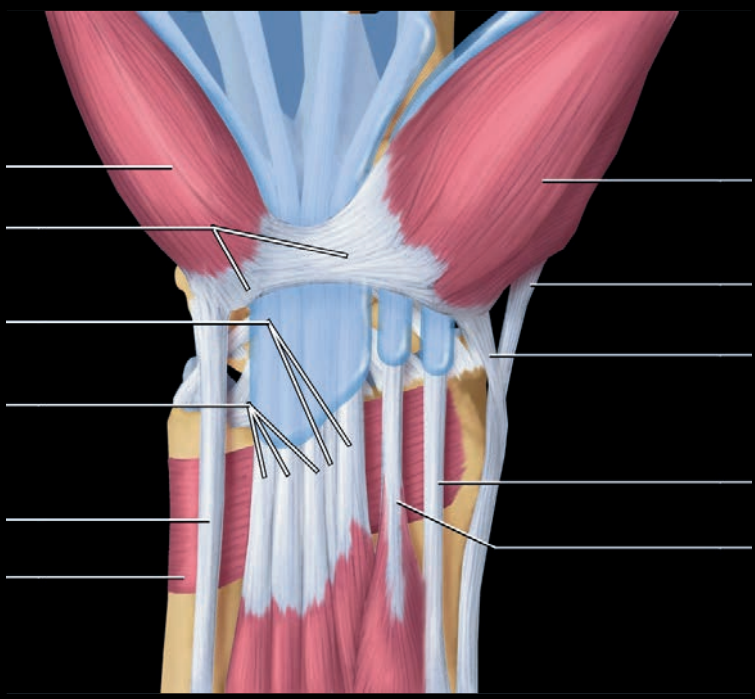
(Top) *Transverse grayscale ultrasound shows the 4th extensor compartment at the distal radius. The 4th extensor compartment contains the 4 extensor digitorum tendons and the extensor indicis tendon, which lies radial to the extensor digitorum tendons. The extensor digiti minimi has a separate compartment.* ***(Middle)*** *Transverse grayscale ultrasound shows the 4th extensor compartment at the level of the proximal carpal row. The extensor retinaculum is a thickened continuation of the antebrachial fascia. It is attached to the anterior aspect of the distal radius, styloid process of the ulna, and the triquetral and pisiform bones.* ***(Bottom)*** *Transverse grayscale ultrasound shows the 4th extensor compartment at the level of the proximal carpal row. The extensor retinaculum holds the extensor tendons in place. Because it is closely applied to the extensor tendons, with anisotropy, it may appear hypoechoic and be confused with tenosynovitis.*

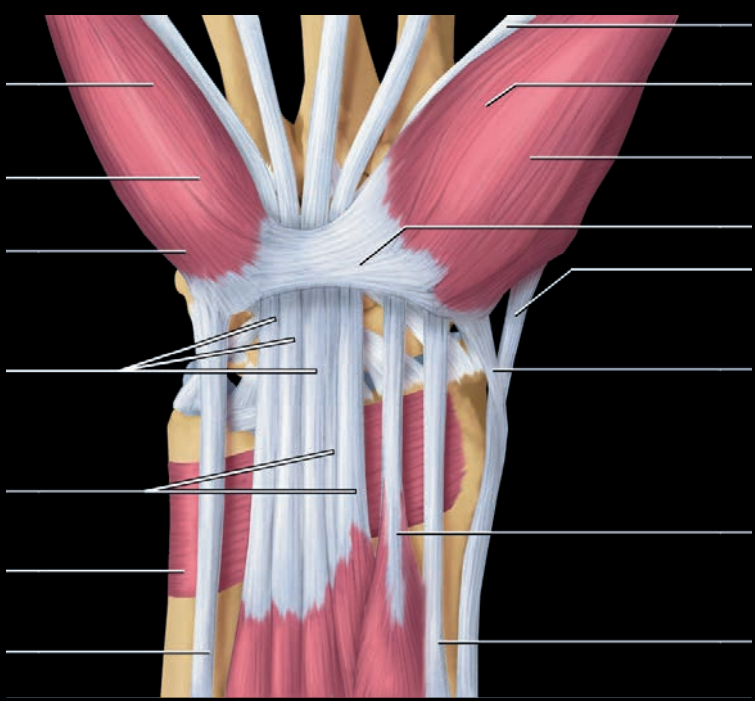
TRANSVERSE US, EXTENSOR CARPI ULNARIS



(Top) *Transverse grayscale ultrasound shows the 5th and 6th extensor compartments. The 5th compartment contains the extensor digiti minimi (EDM) tendon. This tendon is joined by the extensor digitorum (ED) tendon to the little finger just proximal to the metacarpophalangeal (MCP) joint. The 6th compartment contains the extensor carpi ulnaris (ECU) tendon, which runs in a groove in the distal ulna. Its position in the groove will change with pronation and supination.* ***(Middle)*** *Transverse grayscale ultrasound shows the 5th and 6th extensor compartments. The ECU tendon often has a midline irregular hypoechoic line within its substance close to the insertion. This should not be mistaken for a longitudinal tear.* ***(Bottom)*** *Transverse grayscale ultrasound at insertion of the ECU tendon is shown. The ECU tendon widens as it passes the lunate bone on its way to insert into the base of the 5th metacarpal.*

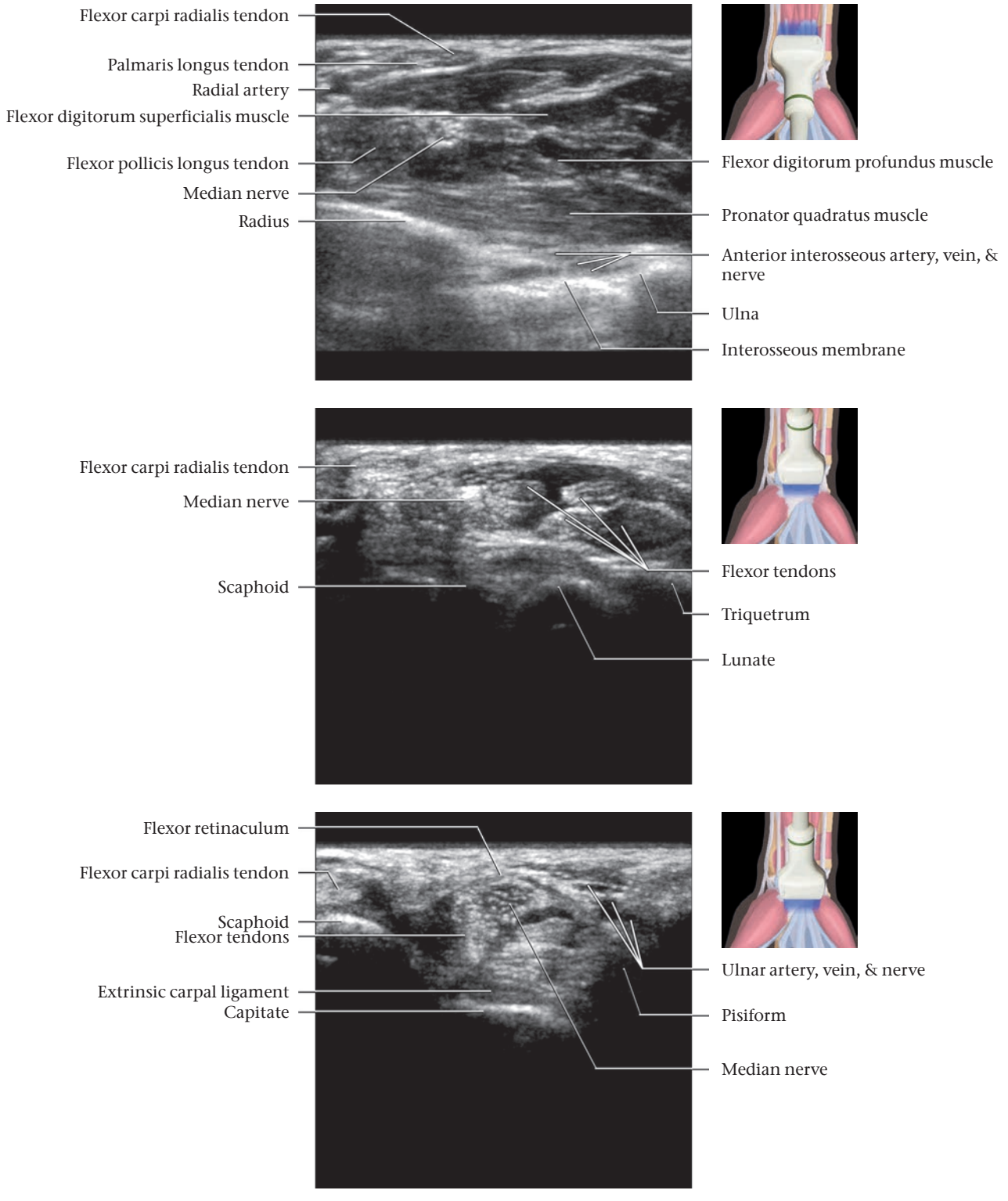
GRAPHICS, VOLAR WRIST





(Top) *Graphic shows tendons and retinaculum of the volar wrist. The flexor retinaculum spans the palmar arch, attaching to the to the tubercle of the scaphoid, the pisiform, the hook of hamate, and the ridge of the trapezium. The thenar eminence musculature includes abductor pollicis brevis, opponens pollicis, flexor pollicis brevis, and adductor pollicis. The hypothenar eminence musculature includes palmaris brevis, adductor digiti minimi, flexor digiti minimi brevis, and opponens digiti minimi.* ***(Bottom)*** *Volar muscles and tendons are displayed with their relation to the flexor retinaculum. Note the muscles of thenar and hypothenar eminences arise from the retinaculum itself. The flexor digitorum and flexor pollicis longus tendons pass deep to the retinaculum. On the radial side, the retinaculum splits to accommodate the flexor carpi radialis tendon.*

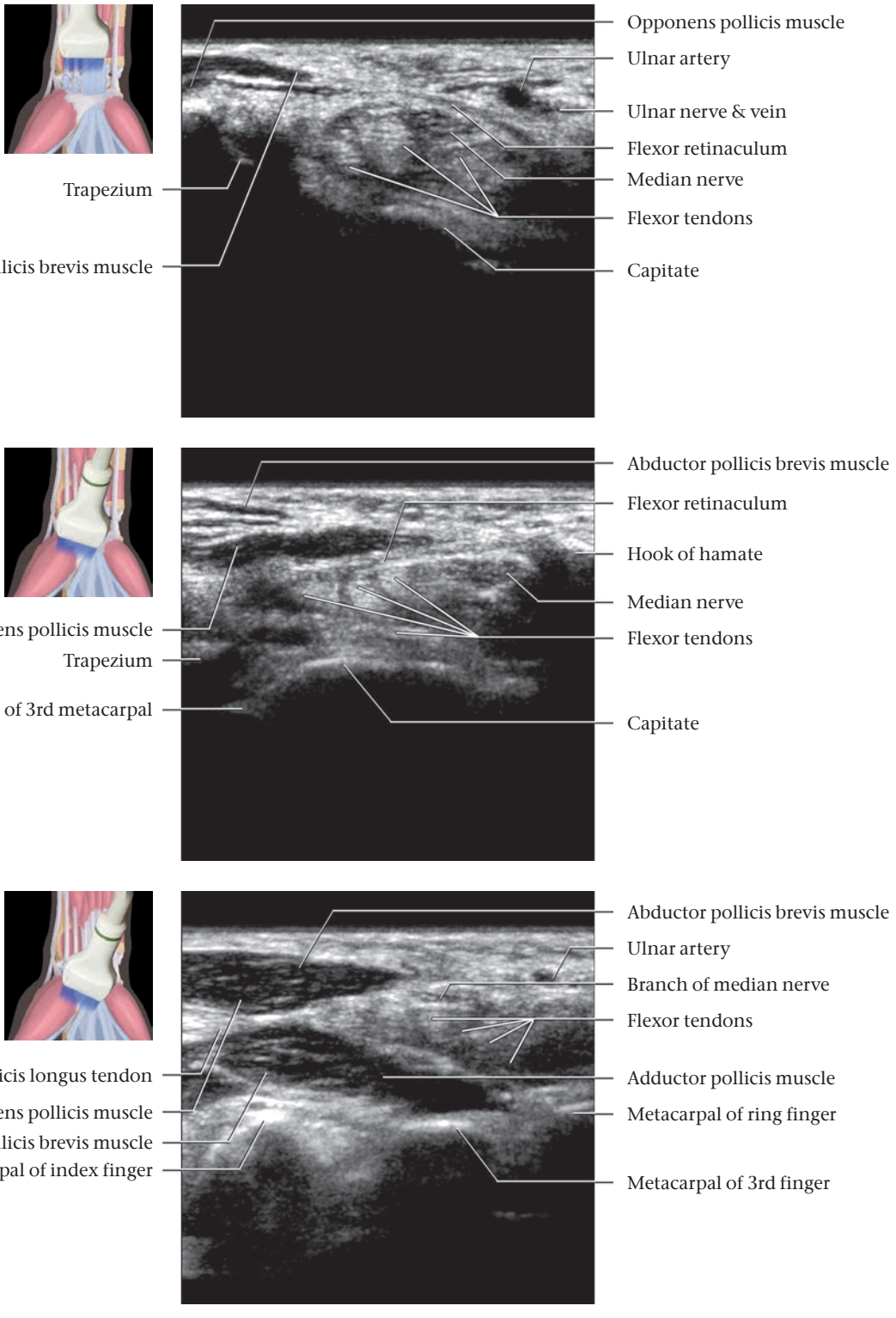
TRANSVERSE US, VOLAR WRIST



(Top) *Transverse grayscale ultrasound shows the volar aspect of the distal forearm just proximal to the wrist. In addition to the tendons that pass through the carpal tunnel, the flexor carpi ulnaris, flexor carpi radialis, and palmaris longus tendons also traverse the wrist joint.* ***(Middle)*** *Transverse grayscale ultrasound shows the volar aspect of the wrist just proximal to the carpal tunnel. The 4 tendons of flexor digitorum superficialis (FDS), 4 tendons of flexor digitorum profundus (FDP), and flexor pollicis longus (FPL) tendons pass through the carpal tunnel. The median nerve dips deeply as it enters the carpal tunnel.* ***(Bottom)*** *Transverse grayscale ultrasound shows the volar aspect of the wrist at the tunnel inlet. The inlet (and outlet) of the carpal tunnel can be best recognized by identifying the proximal and distal margins of the flexor retinaculum. In evaluating carpal tunnel syndrome, the caliber of the nerve should be measured proximal to the tunnel, at the tunnel inlet, and at the tunnel outlet.*

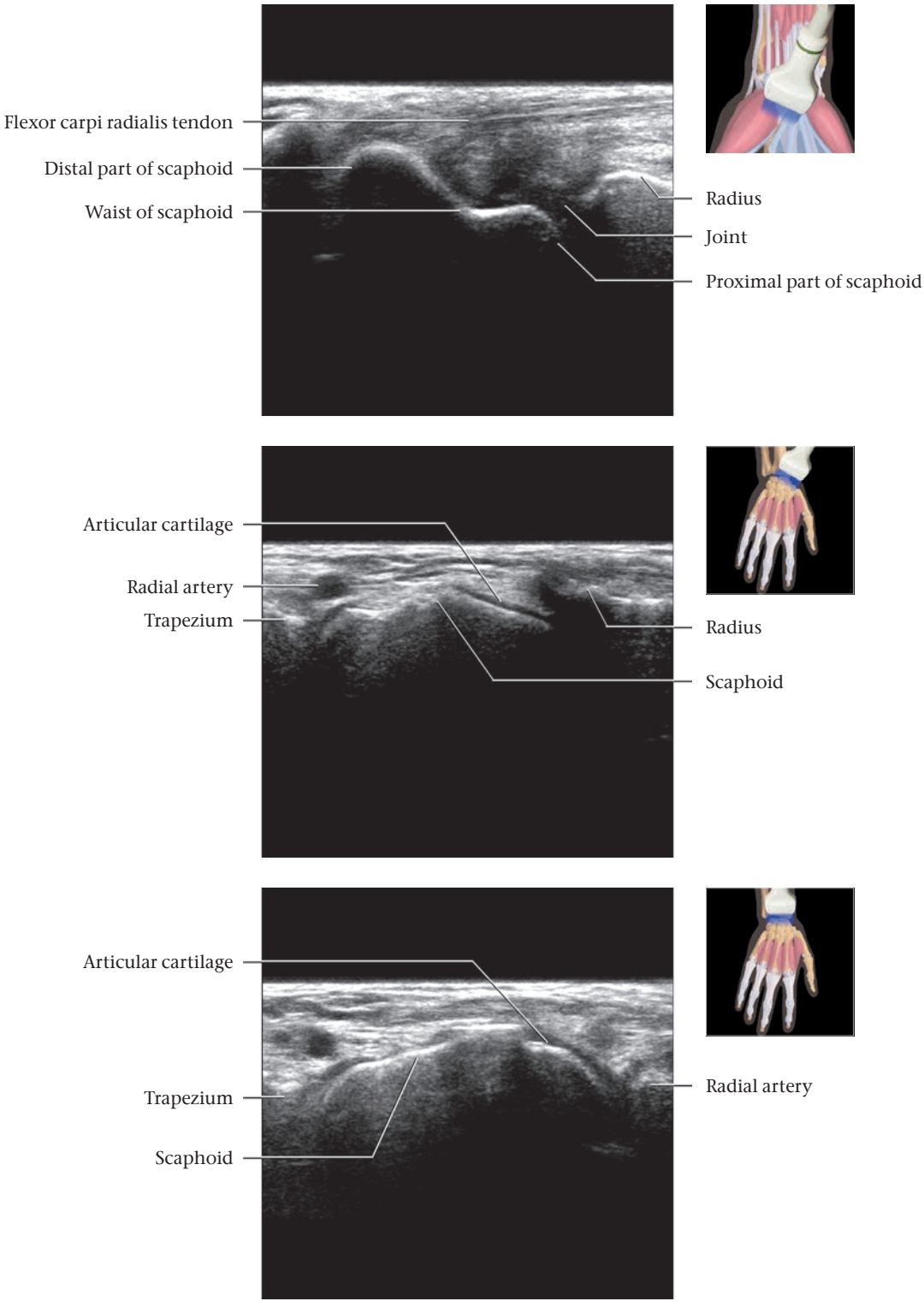
WRIST

US, VOLAR WRIST



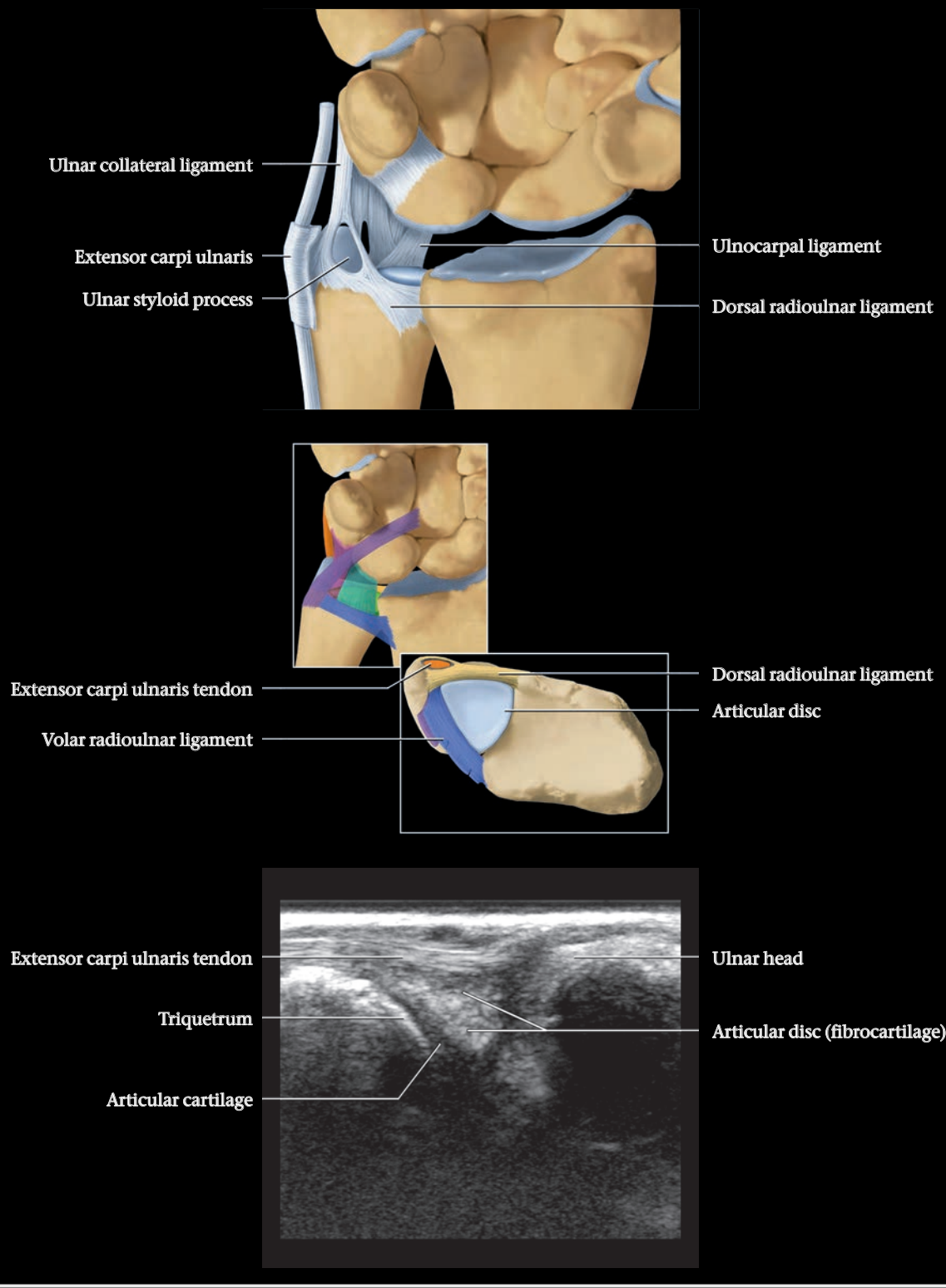
(Top) *Transverse grayscale ultrasound shows the volar aspect at midcarpal tunnel. The median nerve lies in the carpal tunnel just deep to the retinaculum. You may need to use anisotropy to clearly identify the margins of the median nerve separate from the adjacent flexor tendons.* ***(Middle)*** *Transverse grayscale ultrasound shows the volar aspect of the wrist at the tunnel outlet. The tunnel outlet is considered to be the narrowest part of the carpal tunnel.* ***(Bottom)*** *Transverse grayscale ultrasound shows the volar aspect of the wrist just beyond the tunnel outlet. The median nerve divides into its terminal branches just beyond the tunnel outlet.*

US, SCAPHOID



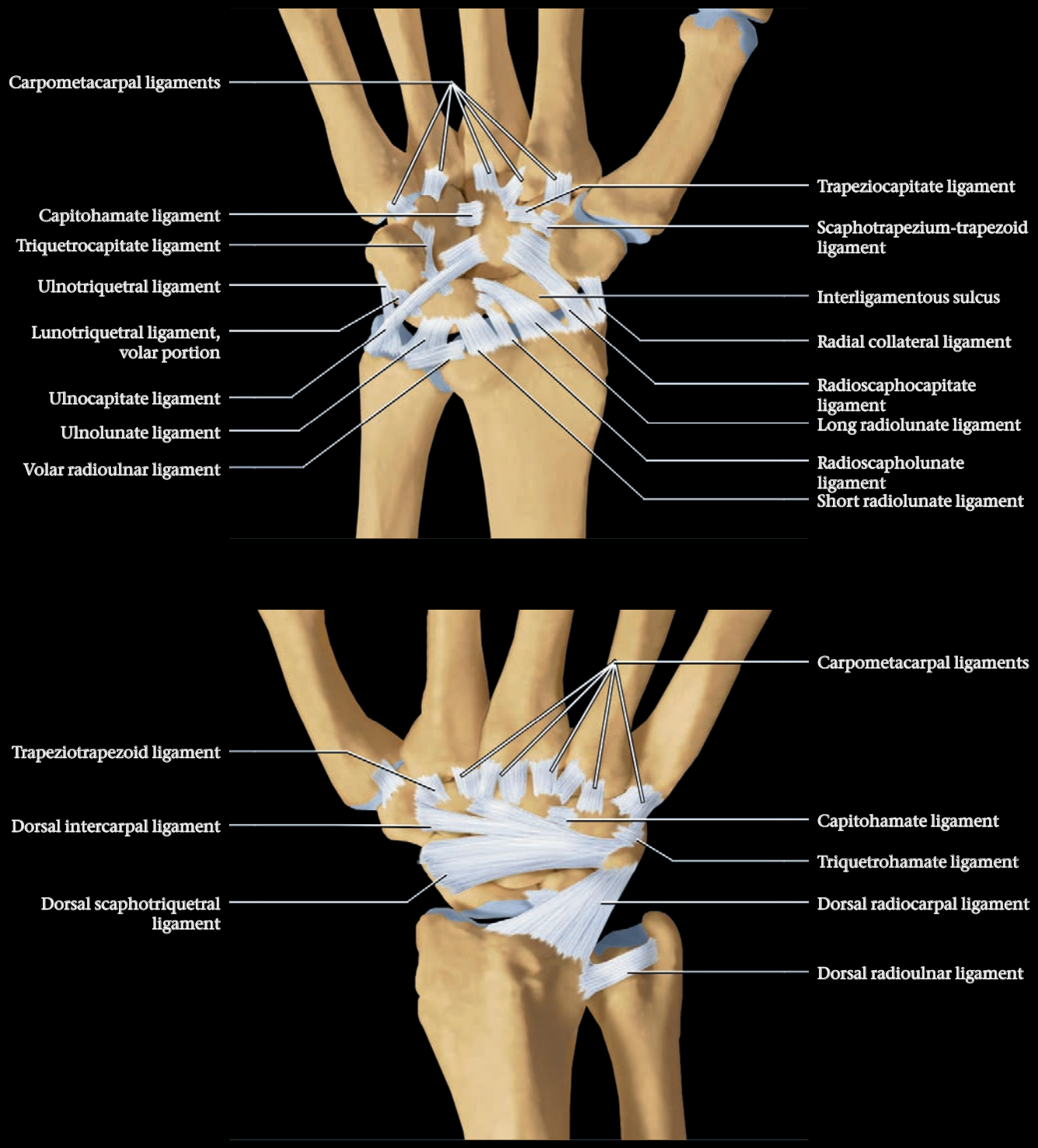
(Top) *Grayscale ultrasound longitudinal to palmar aspect of the scaphoid bone is shown. Ultrasound is a useful means of diagnosing a scaphoid fracture. Angulation of the transducer along the long axis of the scaphoid allows the palmar cortical outline to be appreciated.* ***(Middle)*** *Grayscale ultrasound longitudinal to dorsal aspect of the scaphoid bone is shown. There is often mild cortical irregularity of the scaphoid surface, particularly on the dorsal side. The absence of surrounding edema, hematoma, periosteal thickening, and cortical discontinuity allows one to differentiate this normal appearance from a fracture.* ***(Bottom)*** *Grayscale ultrasound transverse to dorsal aspect of the scaphoid bone is shown.*

GRAPHICS AND US, TRIANGULAR FIBROCARTILAGE



(Top) *Graphic shows supporting structures of triangular fibrocartilage (TFCC). The ulnocarpal ligaments and the volar radioulnar ligament are on the volar side. At the ulnar border, there is the ulnar collateral ligament. On the dorsal surface, there is the extensor carpi ulnaris (ECU) tendon and its subsheath as well as the dorsal radioulnar ligament.* ***(Middle)*** *Graphic depicts the axial view of the articular disc of TFCC. The articular disc is inseparable from supporting dorsal and volar radioulnar ligaments. The disc is widest at its radial attachment. Central tears are more common, while peripheral tears, being better vascularized, have the capacity to heal.* ***(Bottom)*** *Longitudinal grayscale ultrasound shows the ulnar aspect of TFCC. The fibrocartilaginous articular disc is of different echotexture to hypoechoic hyaline cartilage. US is not as sensitive at depicting TFCC tears as MRI. The ECU tendon provides an acoustic window though which to see the articular disc of the TFCC.*

GRAPHICS, VOLAR AND DORSAL LIGAMENTS



(Top) *Graphic shows volar intrinsic and extrinsic ligaments. The extrinsic ligaments connect the bones of the forearm (radius and ulna) and those of the carpus. The intrinsic ligaments connect carpal bones to carpal bones.* ***(Bottom)*** *Dorsal ligaments stabilize and restrict motion but are less critical to the stability of the wrist structures than the volar ligaments. On the volar aspect of the wrist, there is a triangular area of weakness (called the space of Poirier) between the lunate and capitate, which is not covered by any ligaments.*

HAND

EXTRINSIC FLEXOR MUSCULATURE: DIGITS 2 THROUGH 5

Flexor Digitorum Superficialis (FDS)

- Origin: Common flexor tendon origin (medial humeral epicondyle) & midradius
- Insertion: Volar plate proximal interphalangeal joints & bases of middle phalanges digits 2 through 5
- Innervation: Median nerve
- Superficialis tendons split at bases of proximal phalanges into 2 tendon slips
  - Slips pass around flexor digitorum profundus tendon before inserting into middle phalangeal bases
  - FDS forms "tunnel" for flexor digitorum profundus
- Flexes metacarpophalangeal joints (aided by lumbricals & interossei) & proximal interphalangeal joints

Flexor Digitorum Profundus (FDP)

- Origin: Proximal half of radius & interosseus membrane
- Insertion: Volar plates, distal interphalangeal joints, & bases of distal phalanges of digits 2 through 5
- Innervation: Ulnar & median nerves
- Flexes distal interphalangeal joints & proximal interphalangeal, metacarpophalangeal (aided by lumbricals & interossei) joints of digits 2 through 5

INTRINSIC MUSCLES: HYPOTHENAR AREA

Hypothenar Eminence

- Mirror image of thenar eminence
- Muscles: Abductor digiti minimi (ADM), flexor digiti minimi (FDM), opponens digiti minimi (ODM) from superficial to deep
  - Origin: ADM from pisiform
    - FDM & ODM from flexor retinaculum & hook of hamate
  - Insertion: ADM & FDM → conjoint insertion ulnar aspect base of proximal phalanx little finger
    - ODM to proximal 2/3 metacarpal shaft little finger
  - Innervation: All by ulnar nerve

INTRINSIC MUSCLES: THENAR AREA

Thenar Eminence

- Muscles: Abductor pollicis brevis (APB), flexor pollicis brevis (FPB), opponens pollicis (OP)
  - Origin: All from flexor retinaculum & tubercle of trapezium
  - Insertion: APB, FPB conjoint insertion at base of proximal phalanx radial aspect
    - OP to volar aspect 1st metacarpal shaft
- Innervation: All by median nerve except FPB which has also partially supplied by ulnar nerve

Adductor Pollicis Muscle

- Oblique (proximal) & transverse (distal) heads
- Origin: Capitate, trapezoid, 2nd & 3rd metacarpals
- Insertion: Ulnar aspect base of proximal phalanx of thumb, interphalangeal joint, volar plate of thumb
  - Also contributes fibers to extensor hood of thumb, which forms adductor aponeurosis
- Innervation: Ulnar nerve
- Actions: Adducts thumb toward 3rd digit & aids extension of interphalangeal joint
- Separated from thenar muscles by fascial plane & innervated by ulnar rather than median nerve

INTRINSIC MUSCLES: PALMAR AREA

Lumbricals

- Numbered 1-4 from radial to ulnar
- Origin: Radial aspect flexor digitorum profundus tendon index to little fingers
- Insertion: Radial aspect extensor tendon expansion index to little fingers
- Innervation: Most radial two lumbricals by median nerve, most ulnar 2 lumbricals by ulnar nerve
- Actions: Flex metacarpophalangeal joints & extend interphalangeal joints

Palmar Interossei

- Numbered 1-3 from radial to ulnar
- Origin: Mesial palmar aspect diaphyses of 2nd, 4th, & 5th metacarpals
- Insertion: Mesial lateral bands & mesial aspect bases of proximal phalanges of same digit as origin
- Innervation: Ulnar nerve
- Actions: Adduct digits & assist lumbricals with flexion of metacarpophalangeal joints & extension of interphalangeal joints of digits 2, 4, & 5

Dorsal Interossei

- Numbered 1-4 from radial to ulnar
- Origin: Flexor digitorum profundus tendons just distal to carpal tunnel
- Insertion: Radial lateral bands of digits 2-5
- Innervation: Ulnar nerve
- Actions: Extends interphalangeal joints 2-5 and abducts digits 2-5

TENDONS

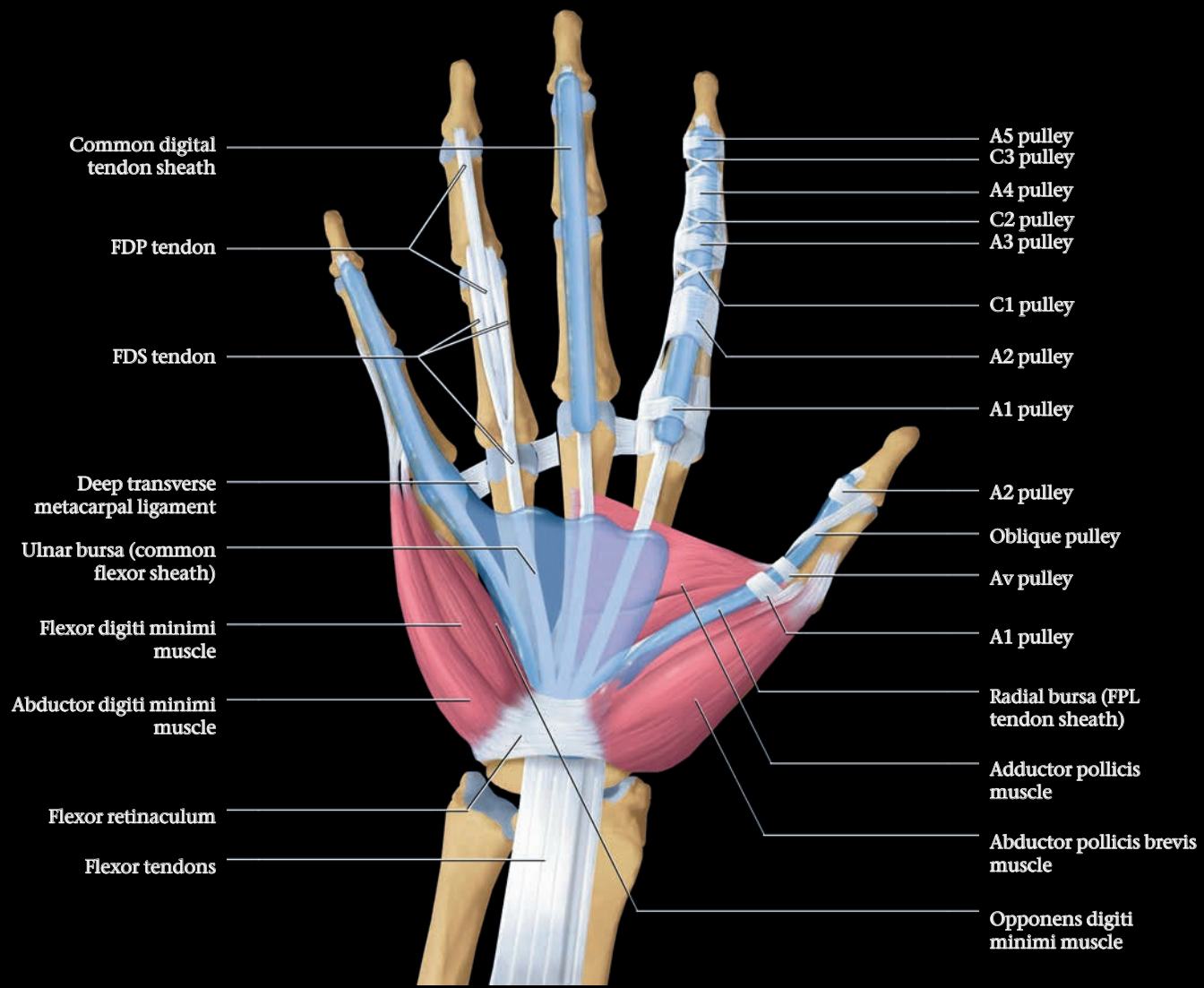
Tendon Sheaths

- Common flexor sheath (a.k.a. ulnar bursa)
  - Contains FDS & FDP tendons
  - Begins just proximal to carpal tunnel
  - Ends just beyond carpal tunnel for digits 2 to 4
  - Encloses 5th digit flexor tendons over entire course to distal interphalangeal joint
- Flexor pollicis longus tendon sheath (a.k.a. radial bursa)
  - Encloses flexor pollicis longus tendon from just proximal to carpal tunnel to tendon insertion at base of distal phalanx thumb
  - ± communication with ulnar bursa at level of carpal tunnel in about 50% of normal population
    - Potential route for spread of infection
- Individual flexor digital sheaths (digits 2 to 4)
  - Encloses flexor tendons from level of metacarpal necks to bases of distal phalanges

Extensor Expansion (or Extensor Hood)

- Expansions of extensor digitorum, extensor indicis, & extensor digiti minimi tendons on dorsum of fingers
  - Help prevent lateral translation of tendon
- 3 bands of extensor expansion
  - Single wide middle band passes over dorsum of proximal phalanx & proximal 1/2 of middle phalanx
  - 2 cord-like lateral bands extend from proximal phalanx to distal phalanx
    - Lumbricals, palmar & dorsal interossei insert into these lateral bands

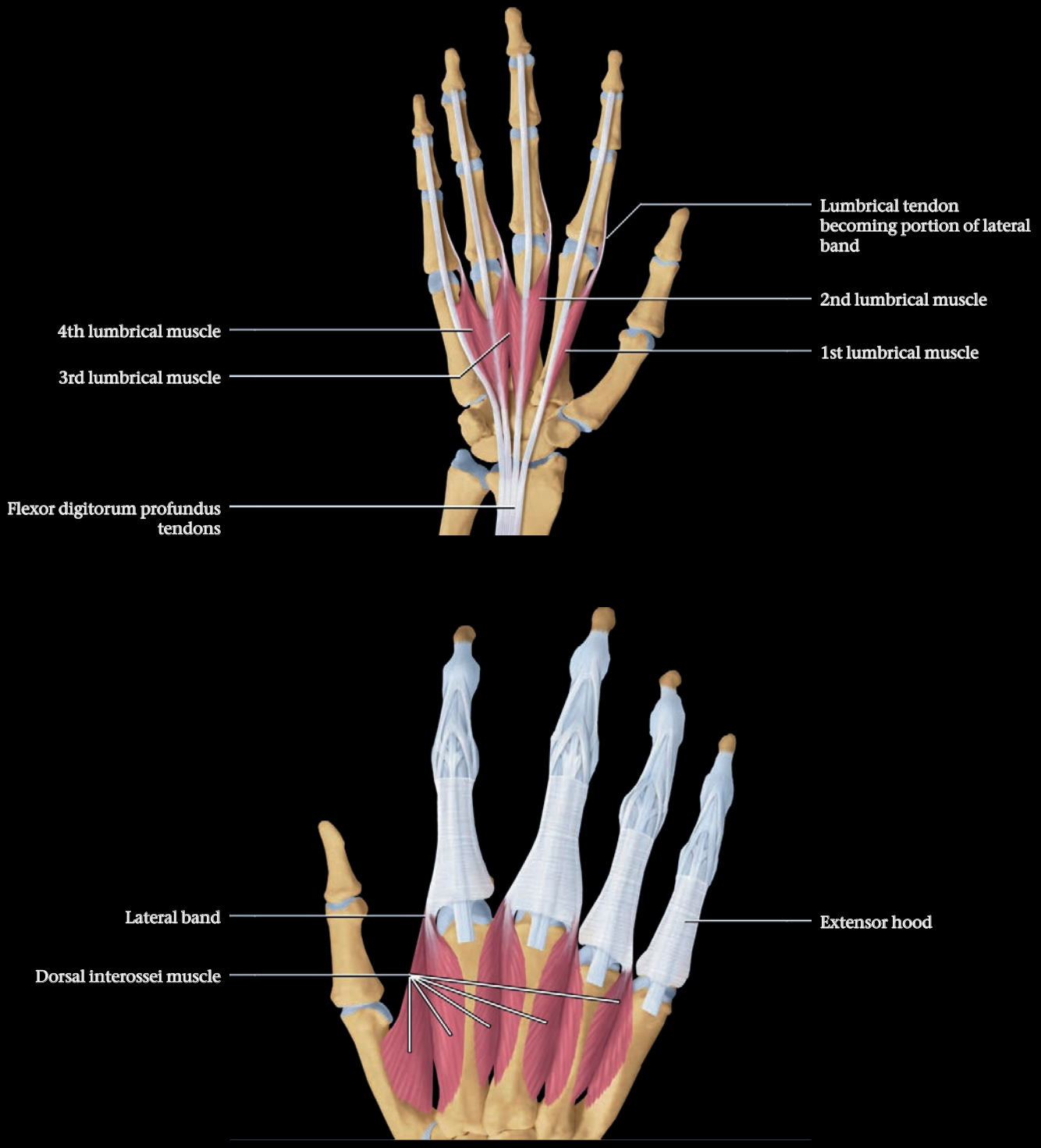
GRAPHIC, PALMAR ASPECT



Pulley system for the 3rd-5th digits is identical to that demonstrated for the 2nd digit. Common digital sheath of the 4th digit is removed to show the relationship of flexor digitorum superficialis (FDS) and flexor digitorum profundus (FDP) tendons. Deep transverse metacarpal ligaments connect the volar plates (not shown) of digits 2-5. Although there is overlap of the radial & ulnar bursae in this image, these structures normally do not invariably communicate. The radial & ulnar bursae may communicate as a normal variation in about 50% of the population. Similarly, any 1 or more of the common digital sheaths may communicate with the ulnar bursa in up to 10% of the normal population. These different bursal communications are important as they provide routes for more extensive spread of infection.

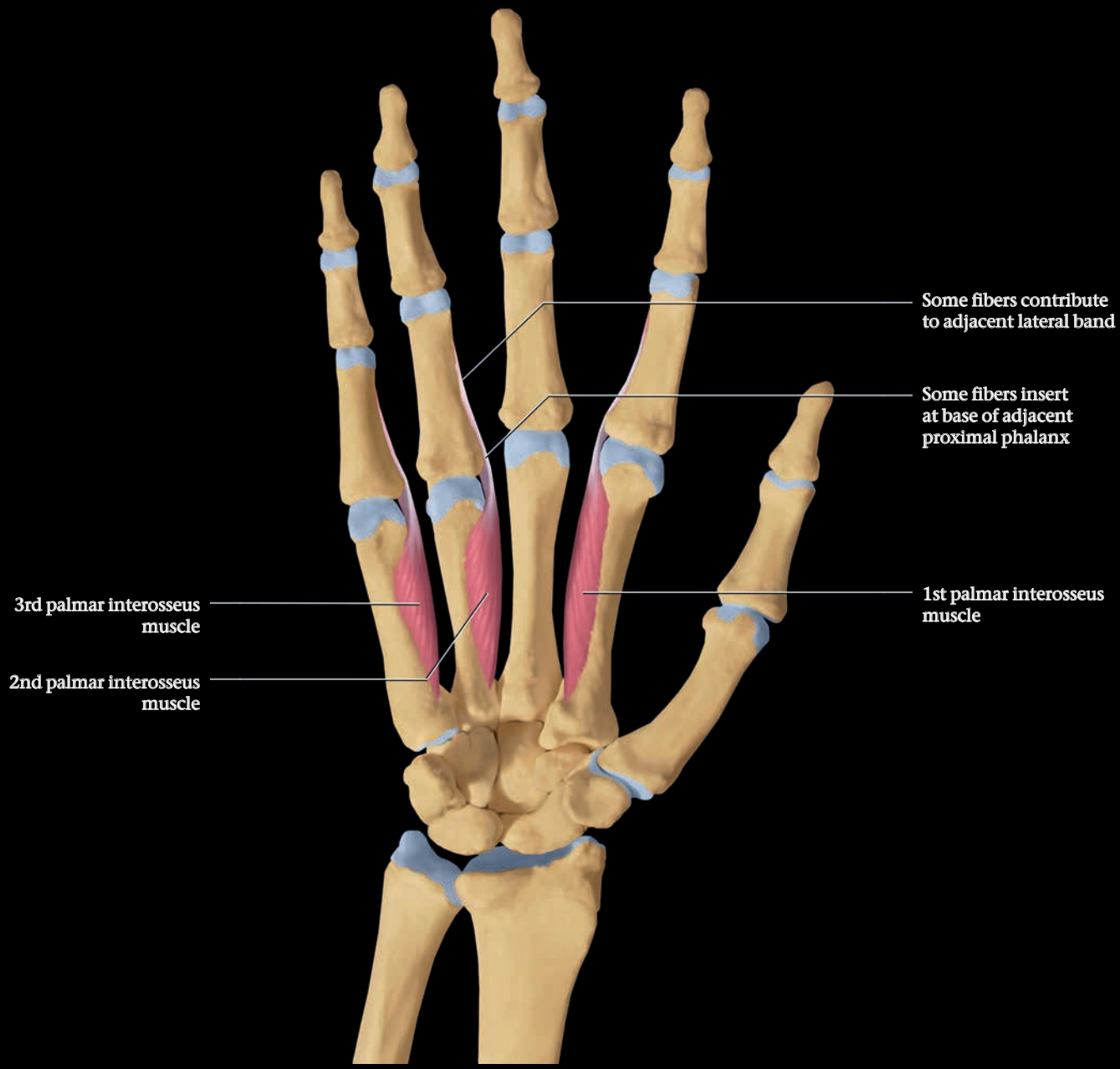
HAND

GRAPHICS, LUMBRICAL AND INTEROSSEI MUSCLES



(Top) *Lumbricals originate from the flexor digitorum profundus tendons as shown. Note how the 1st and 2nd lumbricals arise only from tendons to the 2nd and 3rd digits, respectively (unipennate), whereas the 3rd and 4th lumbrical arise from the tendons to both the 3rd and 4th and the 4th & 5th digits, respectively (bipennate).* ***(Bottom)*** *Graphic of the dorsal surface of the extensor mechanism of the hand and digits 2-5 demonstrates the complex relationship of the various fiber bands. As in imaging, distinction of individual fiber bands is often difficult and must be inferred by knowledge of where the structure "should" be with respect to more easily identifiable structures (such as bones and joints).*

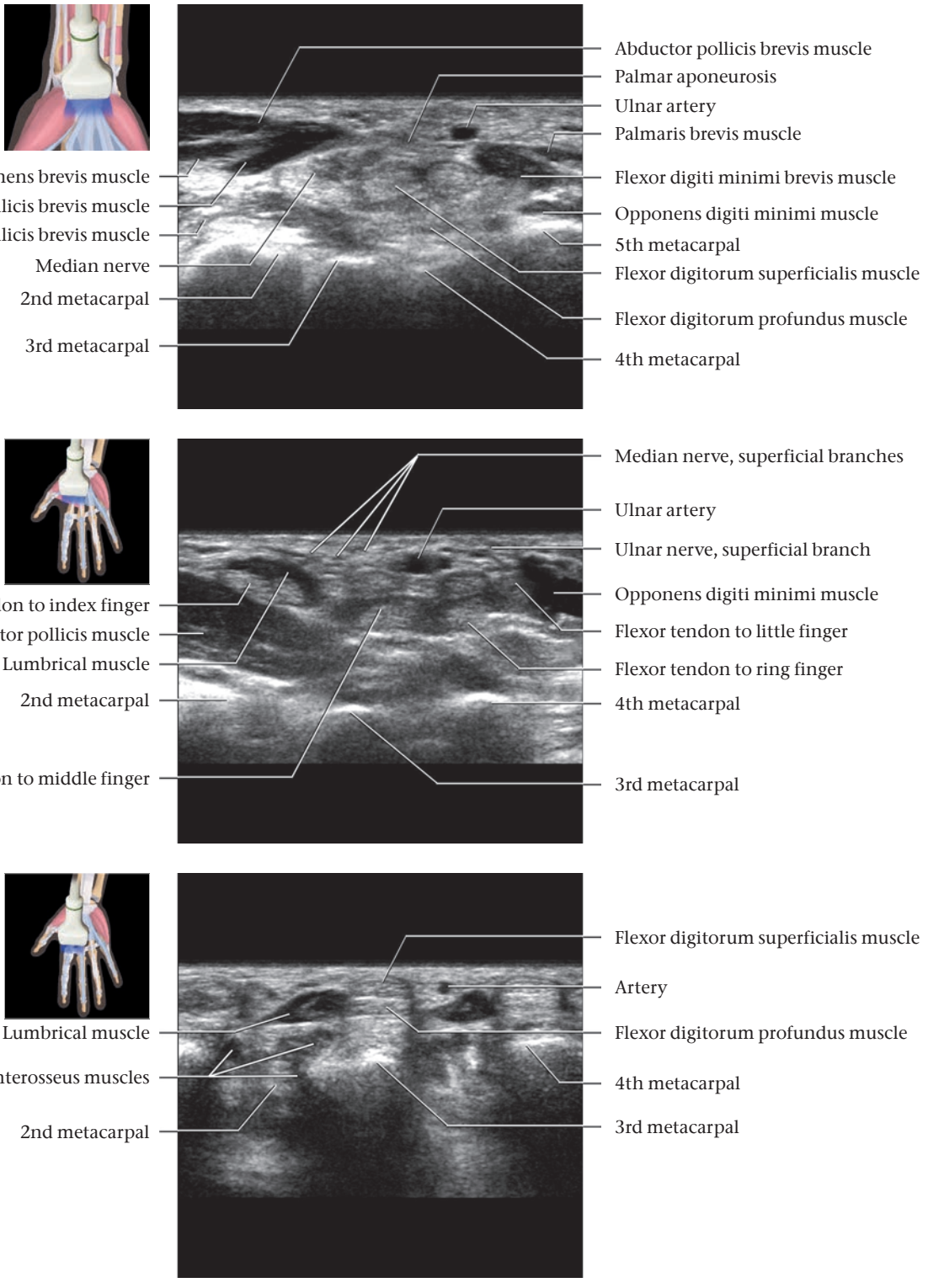
GRAPHIC, PALMAR INTEROSSEI



Palmar interossei insert at both bases of adjacent proximal phalanges as well as adjacent lateral bands. The 2nd & 3rd palmar interossei contribute to the radial lateral bands of the 4th & 5th digits, respectively, whereas the 1st palmar interosseus contributes to the ulnar lateral band of the 2nd digit.

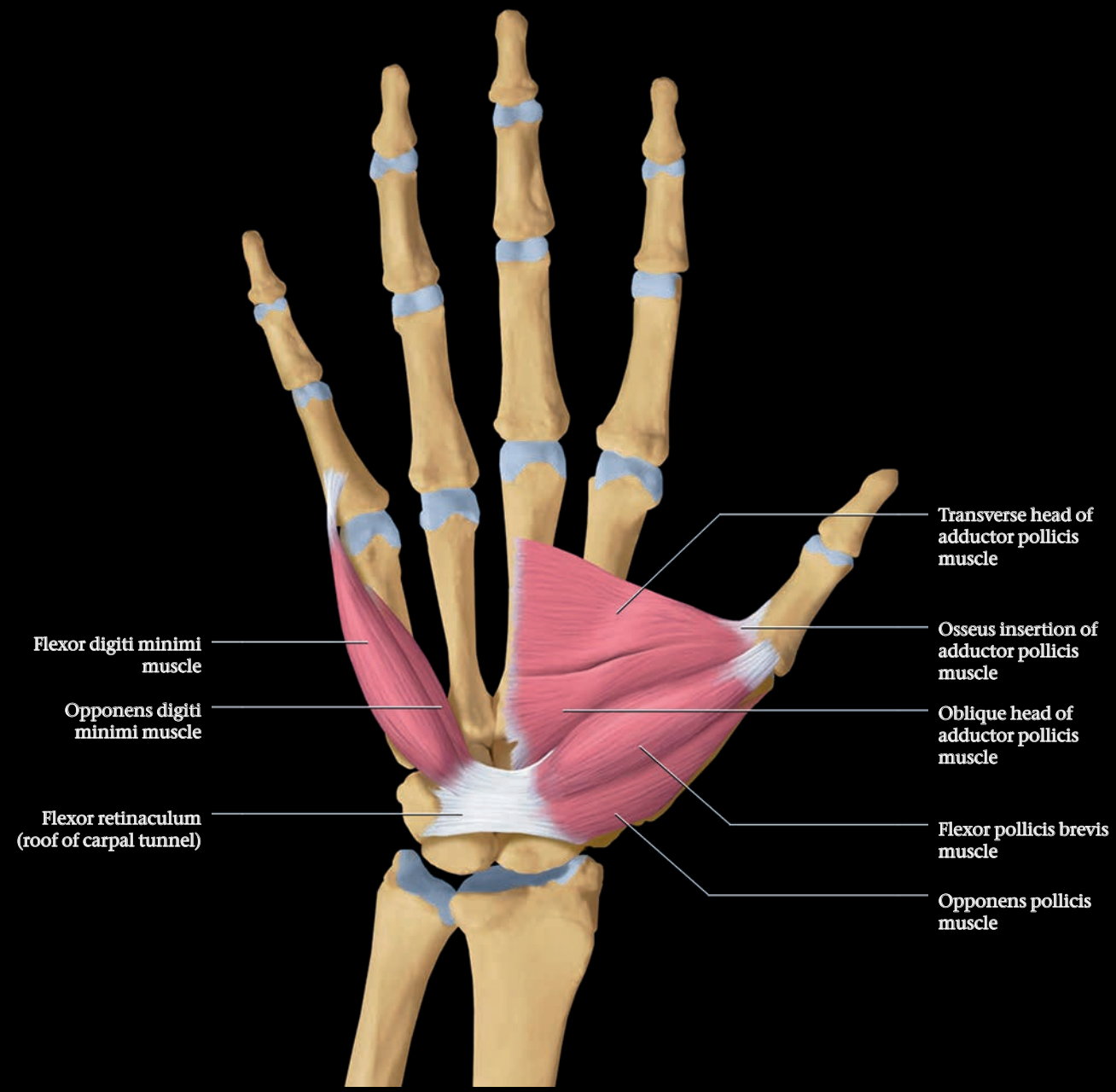
HAND

TRANSVERSE US, PALM



(Top) *Transverse grayscale ultrasound shows the proximal aspect of the palm. The palmar aponeurosis is thin and difficult to demonstrate in the mid to distal palm especially.* ***(Middle)*** *Transverse grayscale ultrasound shows the midportion of the palm. Beneath the aponeurosis lies the flexor tendons, the lumbrical muscles, the muscles of the thenar and hypothenar eminences and, most deeply, the interossei. There are 3 palmar interossei and 4 dorsal interossei muscles.* ***(Bottom)*** *Transverse grayscale ultrasound shows the distal portion of the palm.*

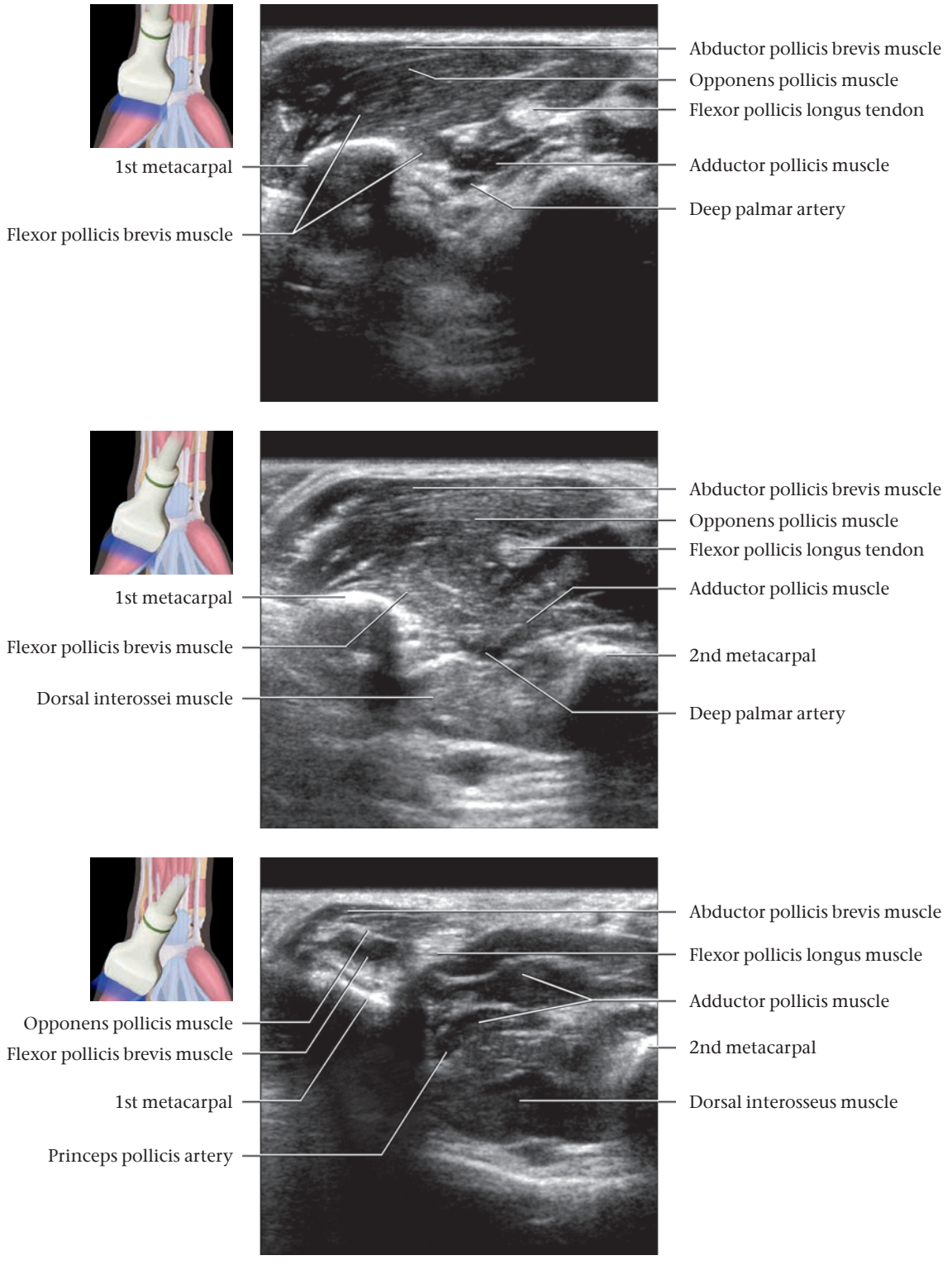
GRAPHIC, THENAR-HYPOTHENAR EMINENCE



Graphic shows the thenar and hypothenar muscles of the hand. Strictly speaking, the adductor pollicis is not one of the thenar group of muscles since it has a separate fascia and separate nerve supply.

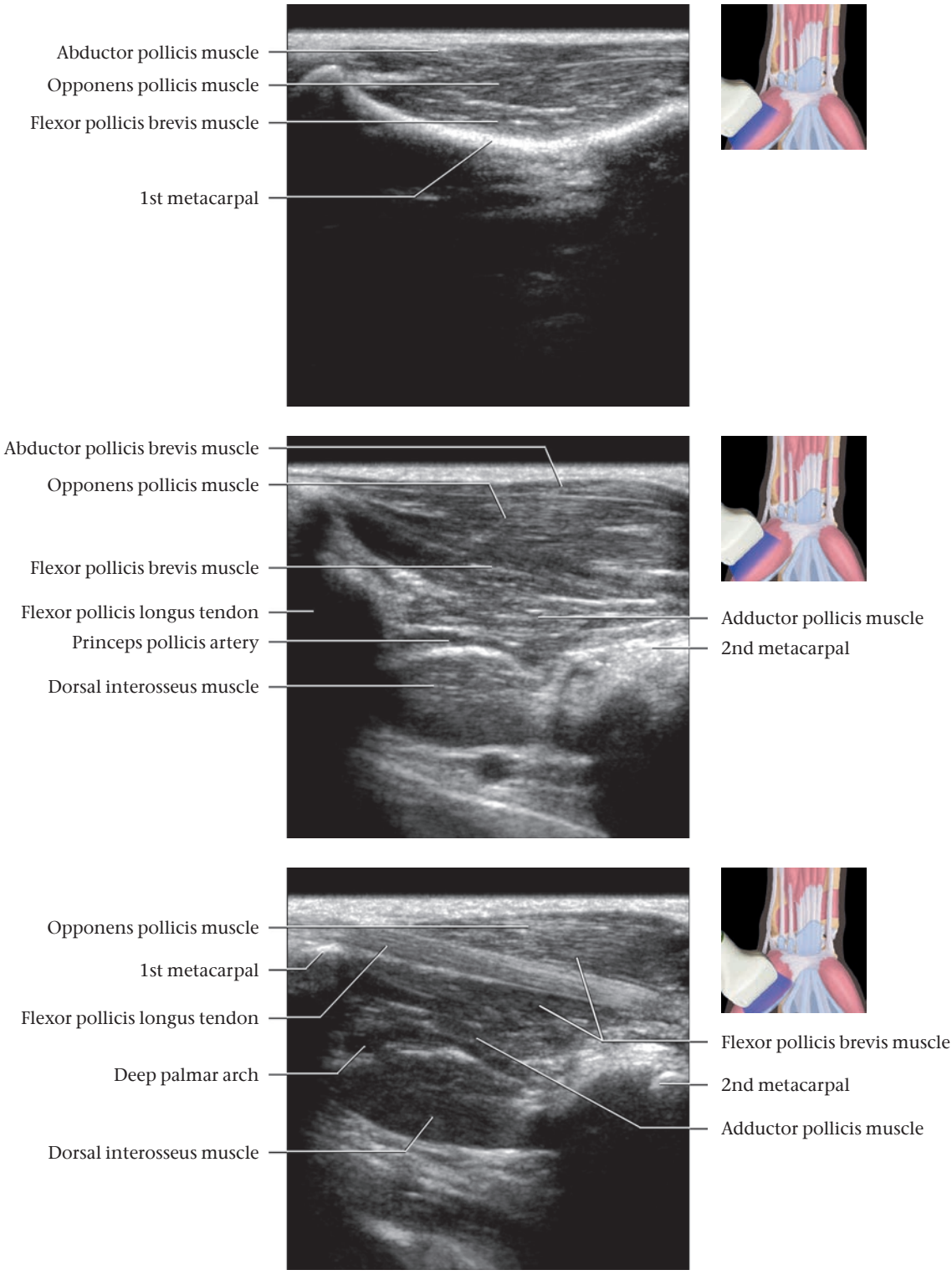
HAND

TRANSVERSE US, THENAR EMINENCE



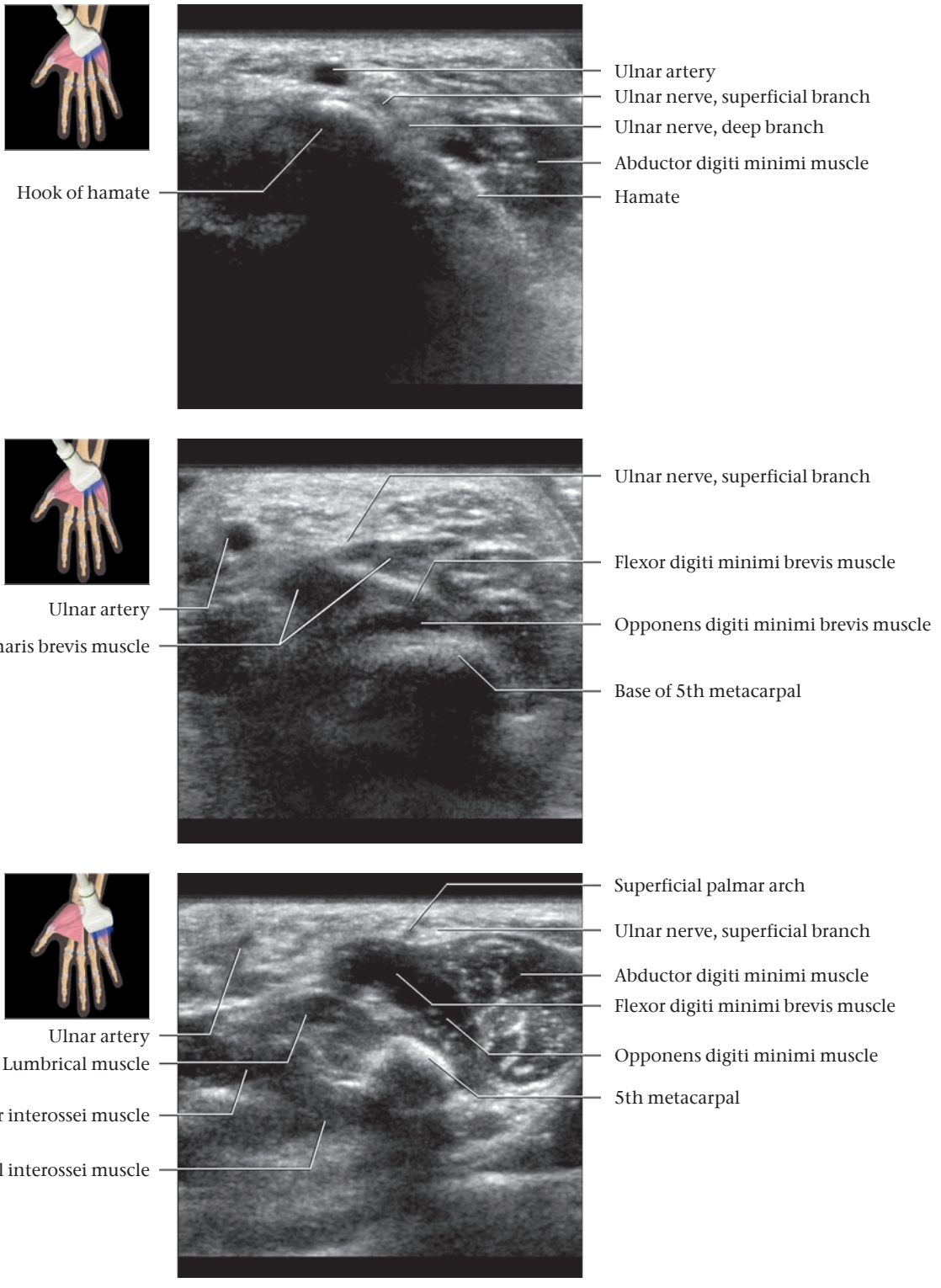
(Top) *Transverse grayscale ultrasound shows the proximal aspect of the thenar eminence. The thenar eminence comprises 4 muscles: Abductor, opponens, flexor, and adductor pollicis from above downwards. The adductor muscle is, strictly speaking, not part of the thenar eminence since it is separated by a fascial layer and has a separate innervation.* ***(Middle)*** *Transverse grayscale ultrasound shows the midportion of the thenar eminence. The flexor pollicis longus tendon is easily recognized as an echogenic tendon alongside the flexor pollicis brevis, deep to the opponens pollicis and superficial to the adductor pollicis muscle.* ***(Bottom)*** *Transverse grayscale ultrasound shows the distal portion of the thenar eminence.*

LONGITUDINAL US, THENAR EMINENCE



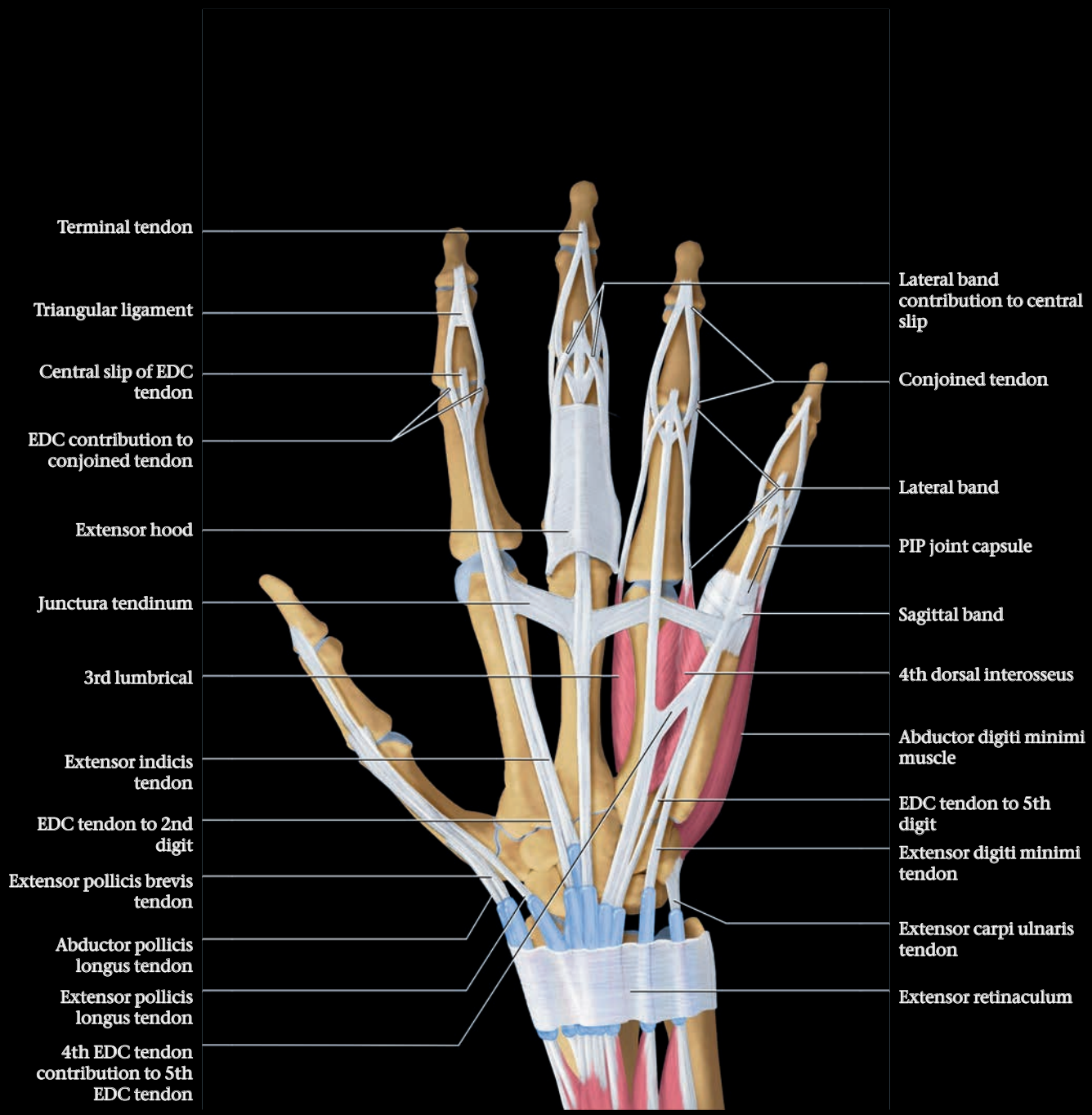
(Top) *Longitudinal grayscale ultrasound shows the proximal aspect of the thenar eminence. Use the mnemonic ABOF to remember the muscles of the thenar eminence.* ***(Middle)*** *Longitudinal grayscale ultrasound shows midthenar eminence. The abductor pollicis brevis, opponens pollicis, and flexor pollicis brevis (ABOF) lie superficial to deep in that order.* ***(Bottom)*** *Longitudinal grayscale ultrasound shows the distal aspect of the thenar eminence. The flexor pollicis longus tendon passes through the more distal aspect of the thenar eminence.*

TRANSVERSE US, HYPOTHENAR EMINENCE



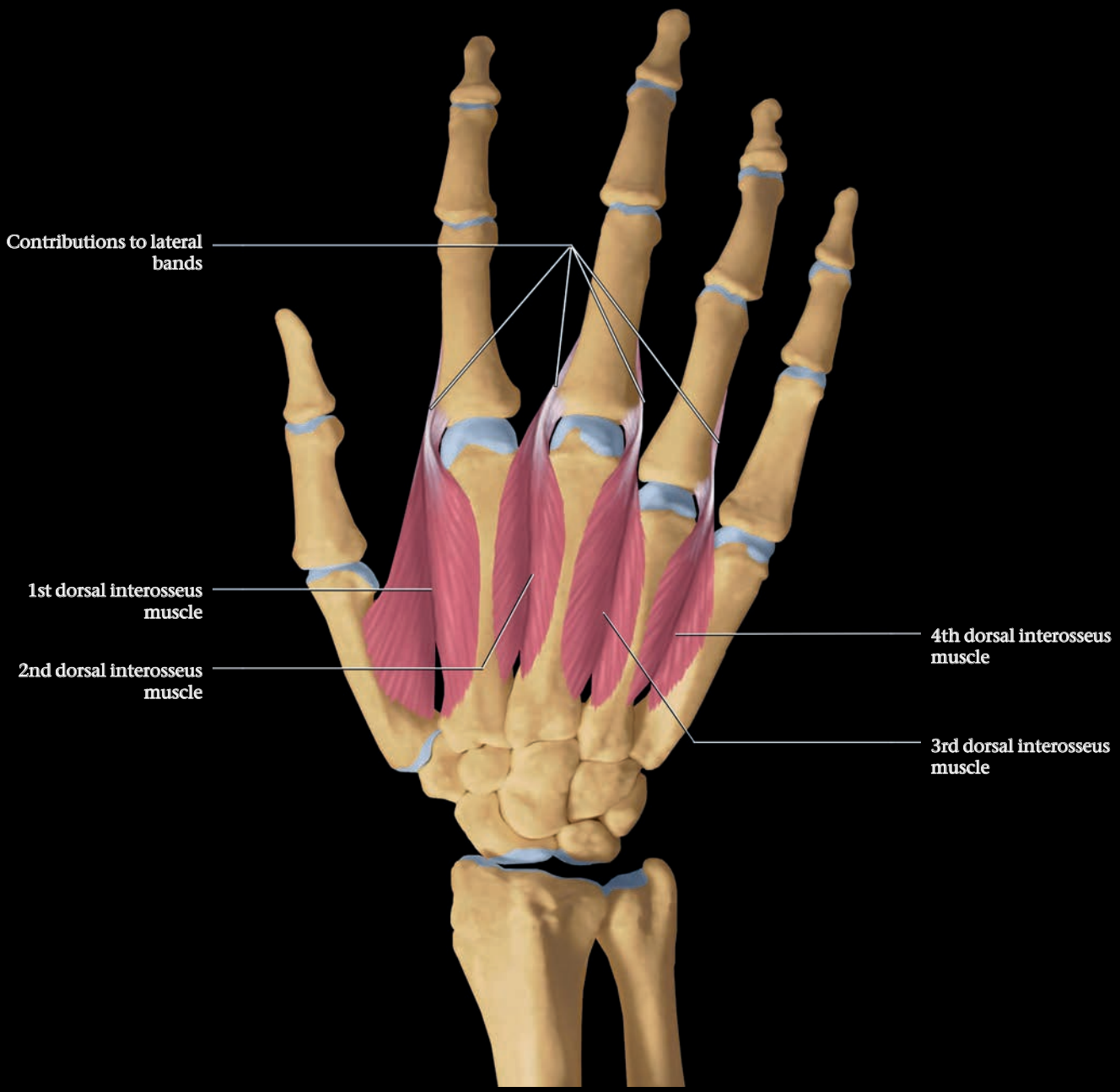
(Top) *Transverse grayscale ultrasound shows the proximal 1/3 of the hypothenar eminence. The hypothenar eminence along with the other muscles of the hand, except for the thenar, are supplied by the ulnar nerve.* ***(Middle)*** *Transverse grayscale ultrasound shows the middle 1/3 of the hypothenar eminence. Hypothenar muscle atrophy can occur with injury to the deep branch of the ulnar nerve just distal to Guyon canal.* ***(Bottom)*** *Transverse grayscale ultrasound shows the distal 1/3 of the hypothenar eminence. The order of muscles in the hypothenar eminence is different from the thenar eminence, with abductor digiti minimi, flexor digiti minimi, and opponens digiti minimi from superficial to deep.*

GRAPHIC, DORSAL ASPECT OF HAND



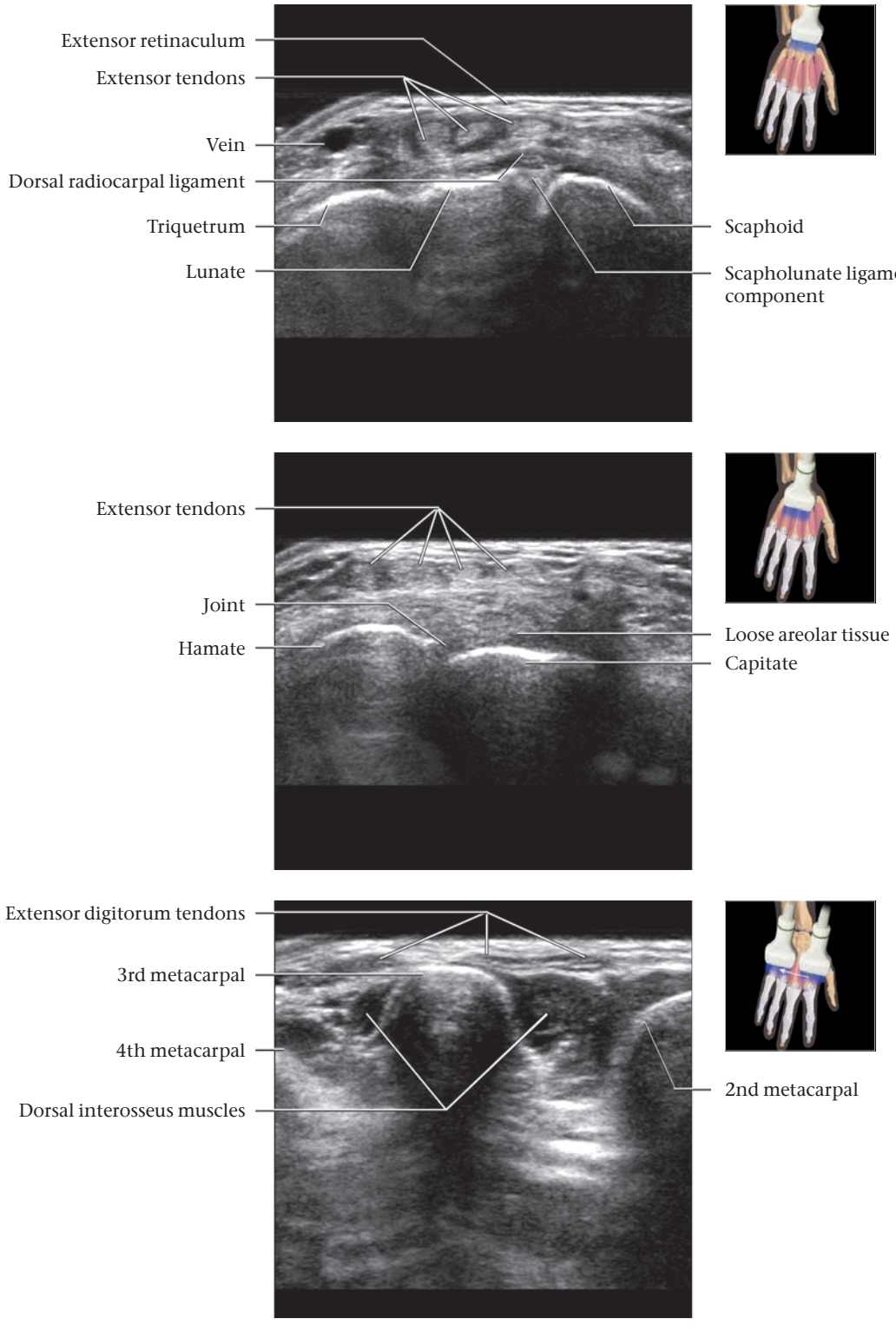
Extensor mechanism composite shows different components of the extensor mechanism on different digits. With the exception of the extensor indicis, extensor digiti minimi, abductor digiti minimi, and 4th EDC tendon contribution to the 5th EDC tendon, any structure on any of the 2nd-5th digits can be extrapolated to any & all of the other 2nd-5th digits. Note that the 2nd extensor retinaculum compartment & its contents (extensor carpi radialis longus & brevis tendons) are not included in this graphic. Although the abductor pollicis longus tendon travels in the 1st compartment of the extensor retinaculum, its insertion (not shown) is actually on the radial aspect of the volar surface of the base of the 1st metacarpal.

GRAPHIC, DORSAL INTEROSSEI



Tendons of the dorsal interossei muscle (along with tendons of the palmar interossei & tendons of the lumbricals) help form lateral bands. Note how each interosseus muscle only contributes fibers to the mesial-most adjacent lateral band. The dorsal interossei do not contribute any lateral band fibers to the 1st or 5th digits.

TRANSVERSE US, DORSUM HAND



(Top) *Transverse grayscale ultrasound shows the proximal aspect of the dorsum hand. The tissues on the dorsum hand are less tightly bound than the tissues on the palmar aspect of the hand, and this part of the hand tends to swell much more with inflammatory or edematous processes.* ***(Middle)*** *Transverse grayscale ultrasound shows the mid aspect of the dorsum of hand. Loose areolar tissue separates the extensor tendons from the metacarpal bones. The extensor tendons do not have a complete tendon sheath from the level of the extensor retinaculum to the insertion.* ***(Bottom)*** *Transverse grayscale ultrasound shows the distal aspect of the dorsal hand. There are 4 dorsal interossei, 1 for each metacarpal interspace.*

HAND VESSELS

TERMINOLOGY

Abbreviations

- Abductor pollicis longus (APL)
- Extensor pollicis longus (EPL)
- Extensor pollicis brevis (EPB)
- Flexor retinaculum (FR)
- Flexor digiti minimi brevis (FDMB)
- Pronator quadratus (PQ)

GROSS ANATOMY

Arteries

- Radial artery
  - Terminal branch of brachial artery
  - Located superficial to pronator quadratus, then continues dorsally around radial styloid process, then passes deep to abductor pollicis longus and extensor pollicis brevis, across anatomic snuffbox and deep to extensor pollicis longus
  - Branches of radial artery
    - Superficial palmar branch continues distally superficial to flexor retinaculum through thenar eminence to anastomose with ulnar artery as superficial palmar arch
  - Deep palmar arch is continuation of radial artery in hand
    - Main radial artery continues dorsally at radial styloid across anatomic snuffbox deep to extensor pollicis brevis and abductor pollicis longus
    - Passes over dorsal aspect of scaphoid bone
    - Passes between heads of 1st dorsal interosseus muscle to enter palm, joins ulnar artery to form deep palmar arch
    - Deep palmar arch is located at level of metacarpal bases 1 cm proximal to superficial palmar arch
    - Lies deep to long flexor tendons and superficial to interossei
    - Deep branch of ulnar nerve lies on convexity of deep palmar arch
    - Princeps pollicis artery, radial artery of index finger, and palmar metacarpal arteries arise from deep palmar arch
- Ulnar artery
  - Terminal branch of brachial artery
  - Located superficial to pronator quadratus, then runs between flexor carpi ulnaris and flexor digitorum superficialis tendons
  - Branches of ulnar artery
  - Common interosseus artery branches in forearm divide into anterior and posterior interosseus arteries
    - Anterior interosseus artery travels distally; at proximal pronator quadratus, gives small branch that pierces membrane, enters dorsal forearm, and anastomoses with posterior interosseus artery
    - Median artery (branch of anterior interosseus artery) arises in forearm and may persist accompanying median nerve into carpal tunnel, contributing to superficial palmar arch
    - Posterior interosseus artery travels distally between deep and superficial extensors to anastomose with anterior interosseus artery
  - Superficial palmar arch is continuation of ulnar artery in hand
    - Located along line extended in arch across palm from thumb web space
    - Similar to metacarpal shaft level ~ 1 cm distal to deep palmar arch
    - Located deep to palmar aponeurosis but superficial to long flexor tendons and digital nerves
    - Common palmar digital arteries arise from superficial palmar arch
    - Run distally on surface of 2nd, 3rd, and 4th lumbrical muscles
    - Near the MCP joints, each common palmar digital artery divides into 2 proper digital arteries
    - Run in subcutaneous fat of digits (lateral aspects)

Veins

- Dorsal venous network of hand and network formed by dorsal metacarpal veins
  - Found on dorsum of hand
  - Unite to form cephalic vein (radial side of wrist) and basilic vein (ulnar side of wrist)
    - Basilic and cephalic veins travel proximally in superficial tissues
    - Both veins unite at antecubital fossa via median cubital vein
    - Continues proximally as cephalic vein until it joins brachial vein in axilla to form axillary vein
  - Layout of superficial veins in hand and forearm is highly variable
- Causes of deep venous thrombosis (DVT) in upper limb extremity are different from that of lower limb
  - Related to IV cannulations, infusions, radiotherapy, effort-induced thrombosis, and malignant obstruction

IMAGING ANATOMY

Overview

- Extensive volar and dorsal anastomoses typically exist

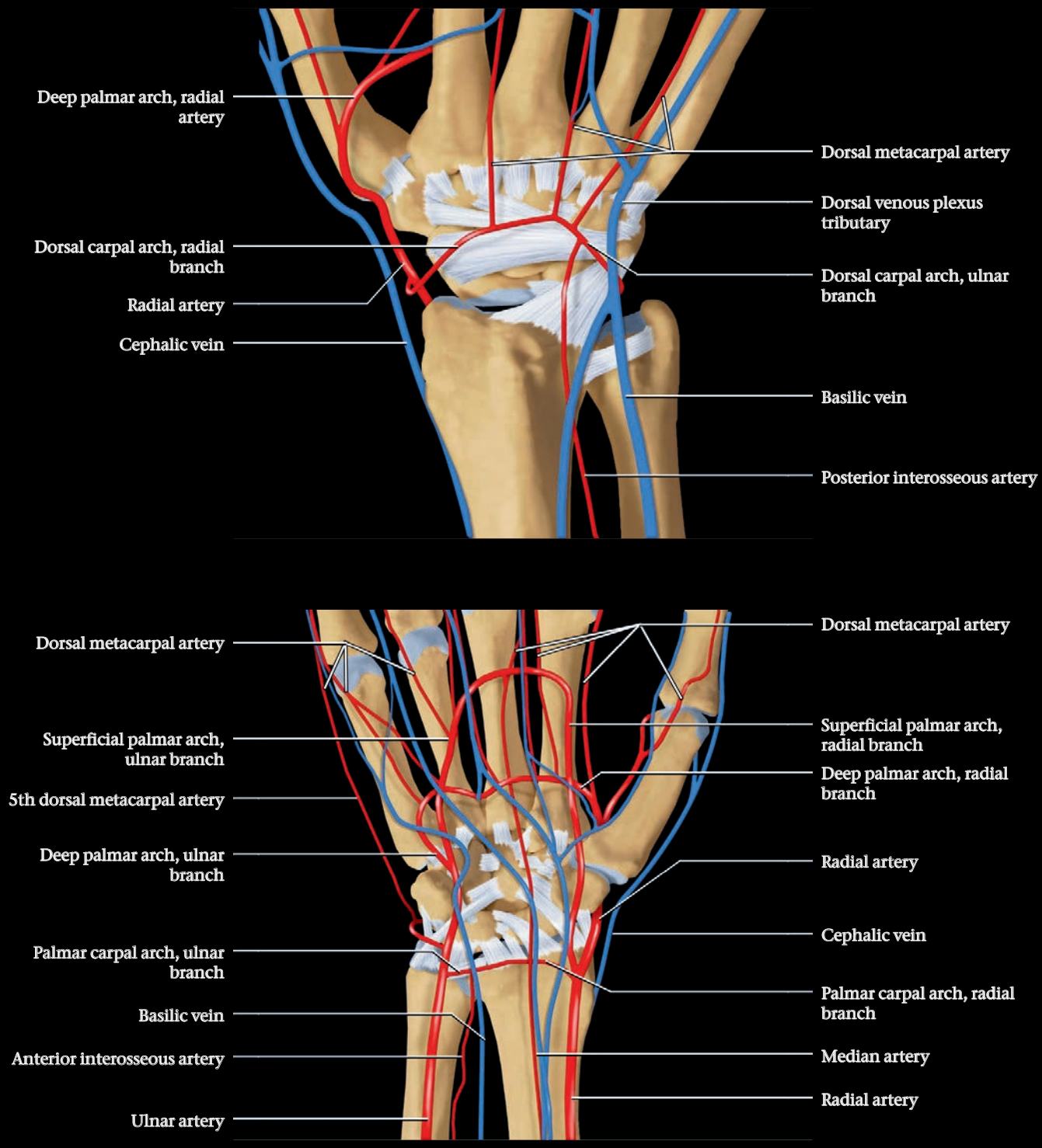
ANATOMY IMAGING ISSUES

Imaging Recommendations

- Assessment of caliber of small arteries of hand best performed by digital substraction angiography as they are close to the limit of resolution by ultrasound
  - For example, when investigating suspected Raynaud disease or Buerger disease

Imaging Pitfalls

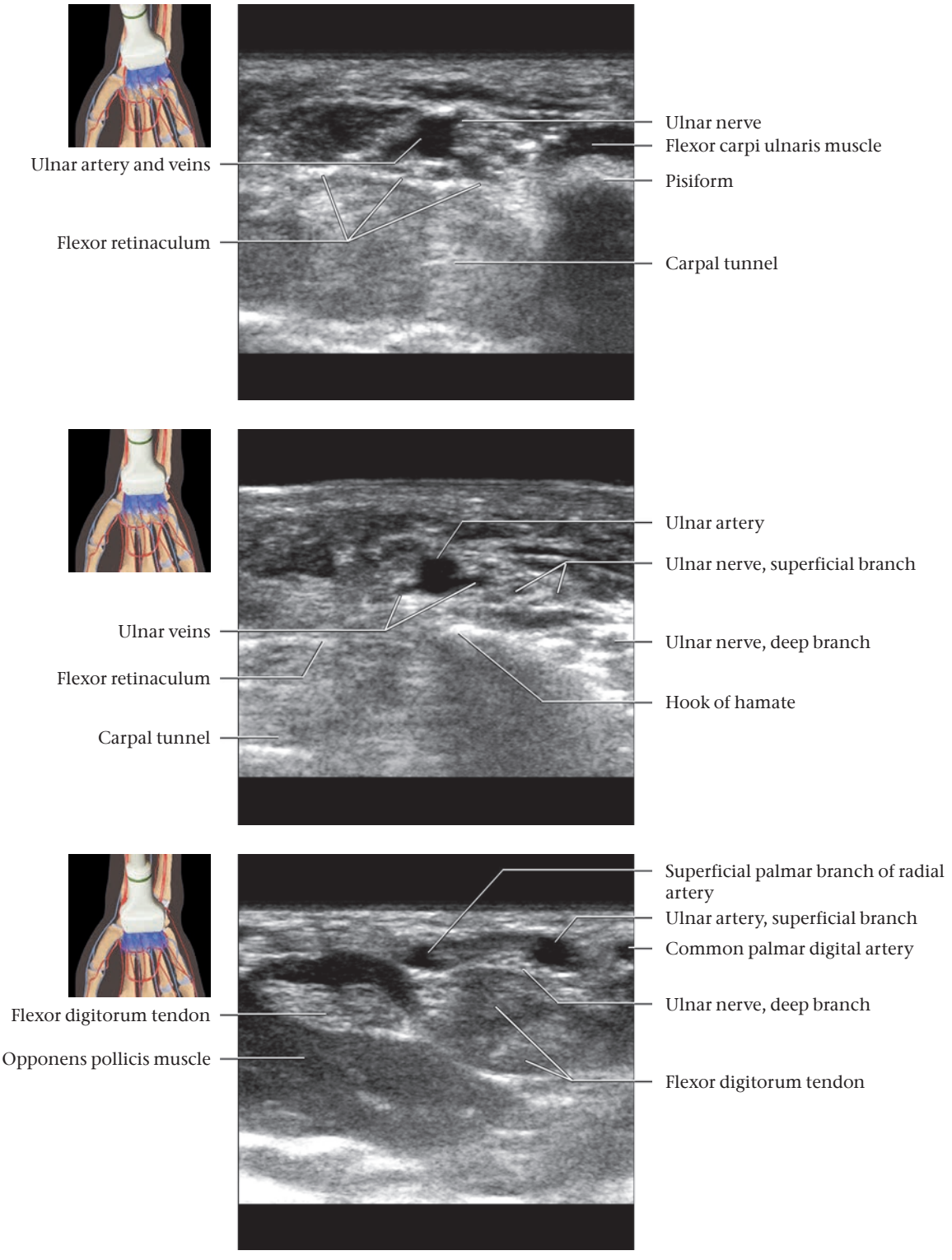
- Vessel visualization on standard imaging is limited
  - Radial and ulnar artery: 2-3 mm, typically visualized
  - Vascular arches: 1 mm, inconsistently visualized
  - Multiple branches and anastomoses, < 1 mm, rarely visualized
- Entry points of nutrient vessels into bone should not be mistaken for erosions
- If angle of insonation of ultrasound beam is at or near 90° to vessel, Doppler and color sensitivity will ↓
- Optimize gate size for small-caliber arteries and position at center of arterial lumen to detect peak flow velocity



(Top) *Vasculature of the dorsal wrist is shown. The dorsal carpal arch supplies the distal radius, distal carpal row, and lateral proximal carpal row. The venous plexus drains into 2 main venous systems, the cephalic and basilic, with multiple anastomotic communications.* ***(Bottom)*** *Vasculature of the volar wrist is shown. Three major arterial arches are contributed to by the radial, ulnar, and interosseous arteries: Palmar (volar) carpal, deep, and superficial palmar arches. A dorsal venous plexus drains into the cephalic and basilic veins.*

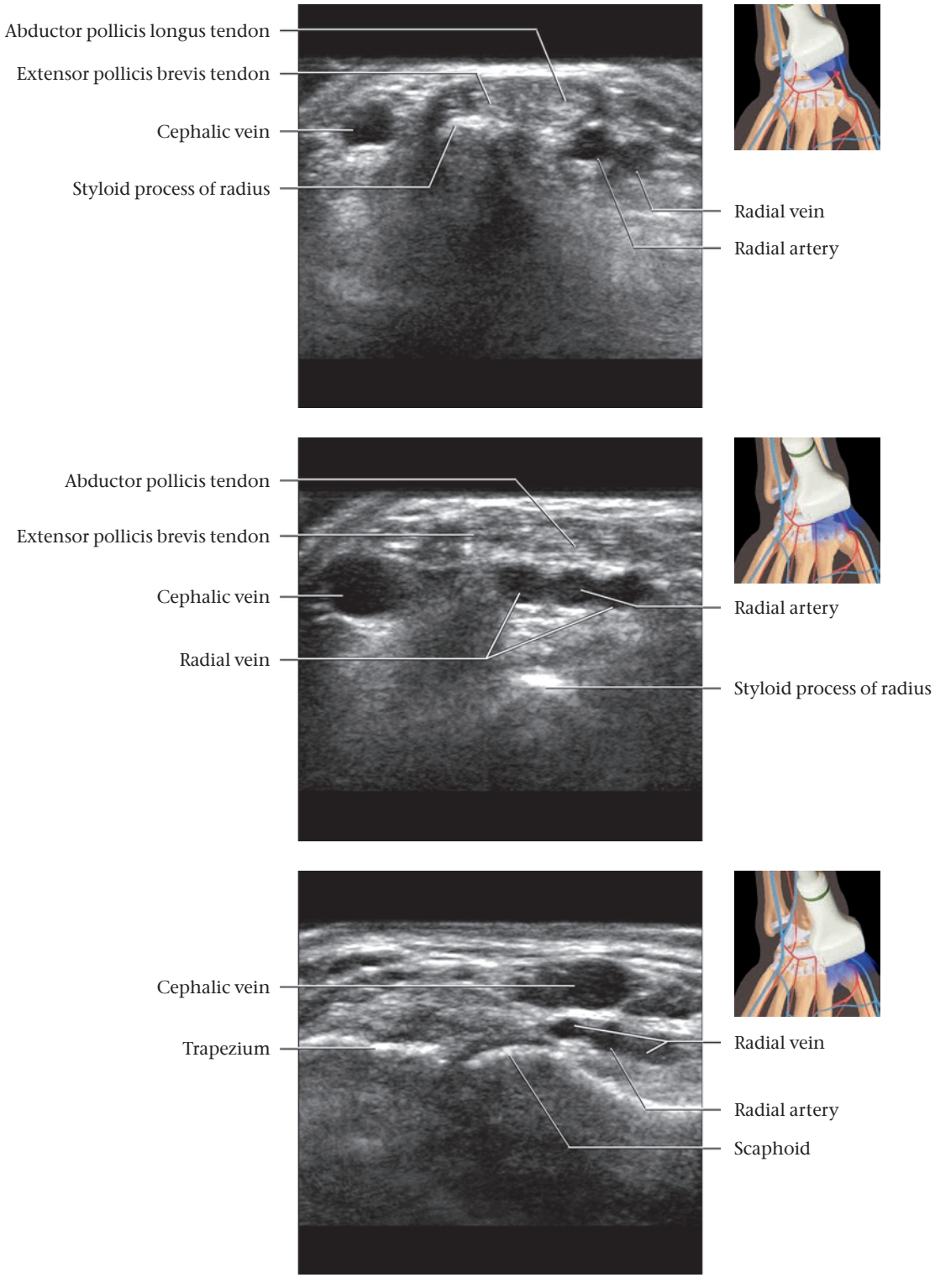
HAND VESSELS

TRANSVERSE US, WRIST AND PALM



(Top) *Transverse grayscale ultrasound shows the ulnar artery at the level of the pisiform bone within Guyon canal. The ulnar artery at the wrist lies on the radial side of the pisiform. Between the ulnar artery and the pisiform lies the ulnar nerve. The ulnar artery divides either within or just beyond the Guyon canal.* ***(Middle)*** *Transverse grayscale ultrasound shows the ulnar artery at the level of the hook of hamate. Here, it is prone to compression injury (hypothenar hammer syndrome), which may damage its walls leading to either thrombosis, occlusion, or aneurysms. It is usually the superficial branch of the ulnar artery that is most prone to hypothenar hammer syndrome.* ***(Bottom)*** *Transverse grayscale ultrasound shows the ulnar artery at the level of the midpalm. The superficial branch of the ulnar artery contributes to the superficial palmar arch.*

TRANSVERSE US, DORSAL ASPECT

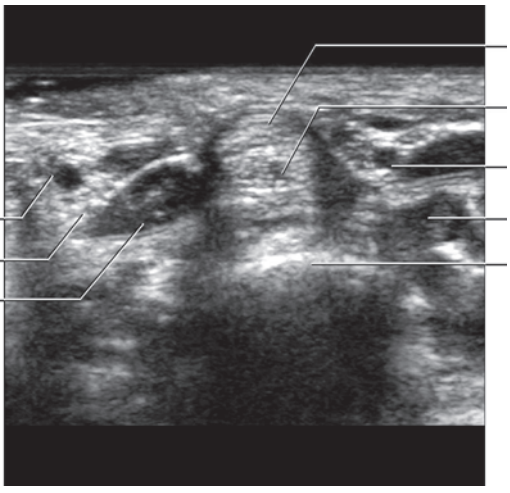


(Top) *Transverse grayscale US shows the radial artery just proximal to the wrist. The radial artery runs a superficial course parallel with the shaft of the radius in the distal forearm. At the wrist, it lies alongside the 1st extensor compartment, comprising abductor pollicis & extensor pollicis brevis tendons.* ***(Middle)*** *Transverse grayscale US shows the radial artery at the wrist joint level. The radial artery runs deep to the 1st extensor compartment tendons. Just before it winds around the wrist, it gives off the superficial palmar branch, which helps form the superficial palmar arch.* ***(Bottom)*** *Transverse grayscale US shows the radial artery at the dorsum of the hand. The deep branch of the radial artery runs on the dorsal surface of the scaphoid & trapezium bones, and then passes deep between the oblique & transverse heads of the adductor pollicis muscle to enter the palm to form the deep palmar arch along with the deep branch of the ulnar artery.*

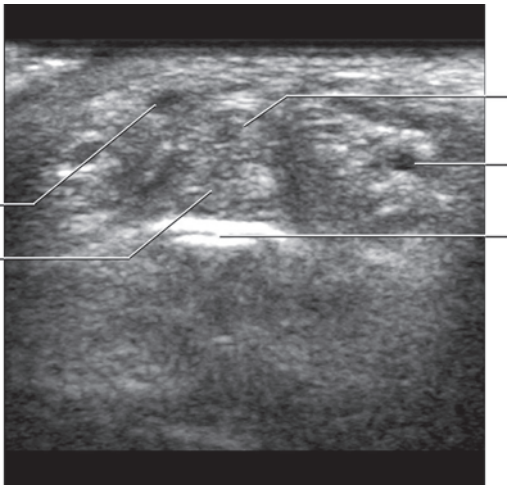
HAND VESSELS

TRANSVERSE US, PALMAR ASPECT

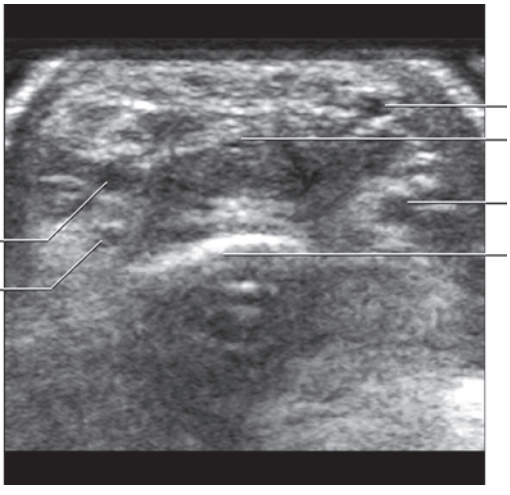






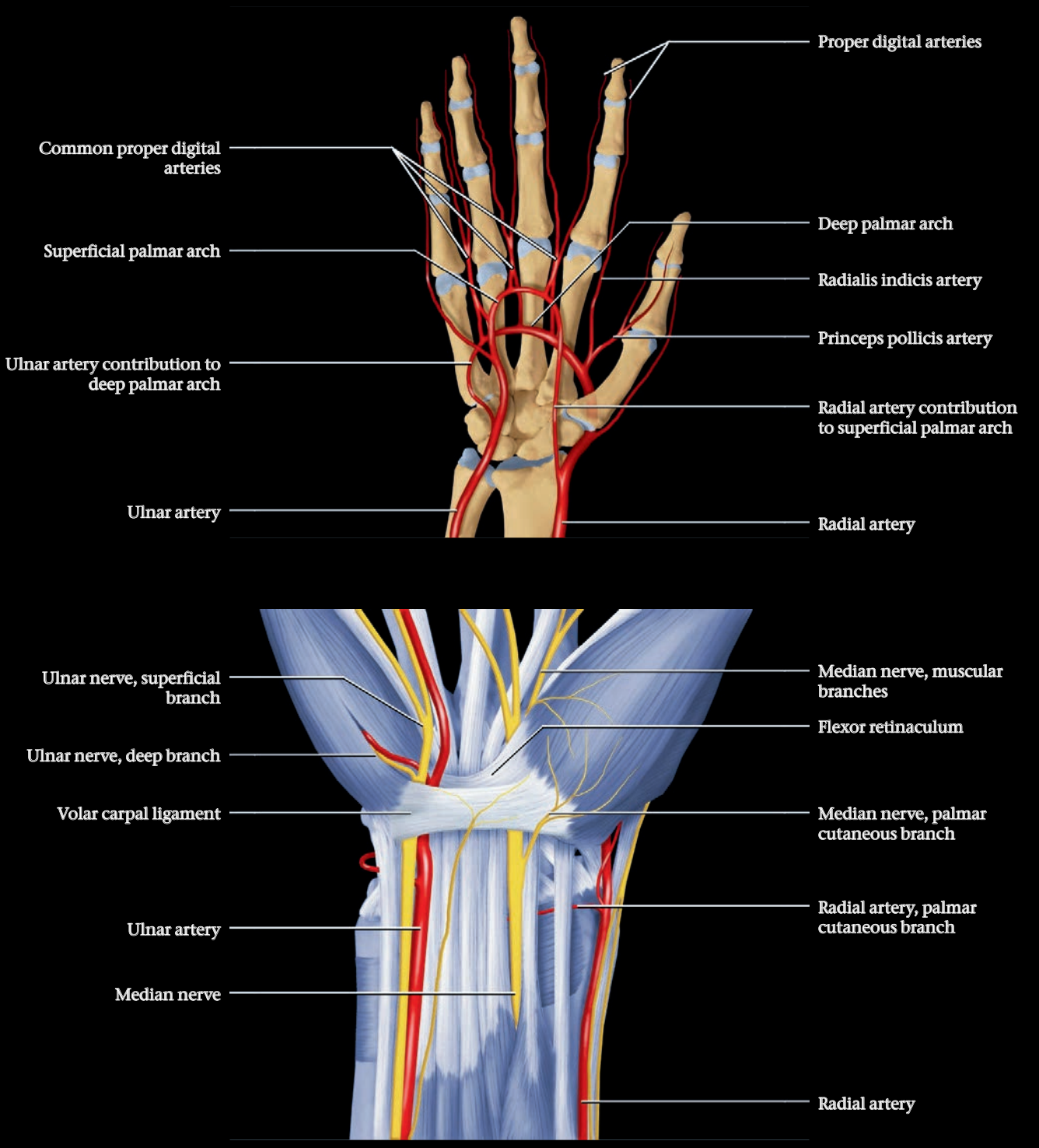






(Top) *Transverse grayscale US shows the vessels of the midpalm at the midmetacarpal shaft level. The common palmar digital arteries arise from the superficial palmar arch and divide at the finger bases into proper digital arteries. Each finger has 4 (2 volar, 2 dorsal) proper digital arteries.* ***(Middle)*** *Transverse grayscale US shows the digital vessels at the proximal phalanx level. The palmar digital arteries lie dorsal to the digital nerves. The palmar digital arteries are usually bigger than the dorsal digital arteries. Ulno-palmar arteries are 2x as big as the radiopalmar arteries (1.8 mm vs. 1.1 mm). Peak systolic velocity (PSV) in hand arteries is variable, ranging 30-70 cm/s.* ***(Bottom)*** *Transverse grayscale ultrasound shows vessels at the middle phalanx level. The veins of the fingers and the hand are variable in number and location. Dorsal veins are of variable size, ranging 1.0-1.5 mm.*

GRAPHICS, HAND ARTERIES



(Top) *Graphic shows the hand arteries. After giving off its contribution to the superficial palmar arch, the radial artery travels around the radial aspect of the wrist to the dorsum of the hand where it travels deep in the anatomic snuffbox. It then dives into the 1st interspace between the heads of the 1st dorsal interosseus muscle as well as between the transverse and oblique heads of the adductor pollicis muscle before forming the deep palmar arch.* ***(Bottom)*** *Graphic shows the relationship of the nerves and arteries to the volar carpal ligament (superficial fibers of flexor retinaculum that form the roof of the Guyon canal) and flexor retinaculum (which forms the roof of the carpal tunnel). The ulnar nerve (and accompanying artery) pass deep to the volar ligament before branching into the deep and superficial branches.*

THUMB

TERMINOLOGY

Abbreviations

- Abductor pollicis brevis (APB)
- Extensor pollicis longus (EPL)
- Extensor pollicis brevis (EPB)
- Flexor digitorum superficialis (FDS)
- Flexor digitorum profundus (FDP)
- Flexor pollicis longus (FPL)
- Flexor pollicis brevis (FPB)
- Metacarpophalangeal (MCP)
- Opponens pollicis (OP)
- Adductor pollicis (AP)

GROSS ANATOMY

Muscles

- Thenar muscle
  - Composed of 4 muscles
    - APB
    - FPB
    - OP
    - AP
  - Origin: All originate from flexor retinaculum and tubercle of trapezium
    - APB also originates from tubercle of scaphoid
  - Insertion: APB and FPB share combined insertion at base of proximal phalanx radial aspect
    - OP inserts onto volar aspect 1st metacarpal
  - AP is often grouped with thenar muscles but is anatomically distinct from them
    - AP is separated from thenar muscles by a fascial plane and innervated by ulnar nerve rather than median nerve
- Extensor muscles
  - EPL
    - Origin: Midulna and interosseus membrane
    - Insertion: Dorsal aspect base of distal phalanx of thumb
    - Extends both MCP and interphalangeal joints of thumb
  - EPB
    - Origin: Distal radius and interosseus membrane
    - Insertion: Dorsal aspect base of proximal phalanx of thumb
    - Extends MCP joint of thumb
- FPL
  - Origin: Midradius and interosseus membrane
  - Insertion: Base of distal phalanx of thumb
  - Flexes MCP and interphalangeal joints of thumb
  - FPL tendon sheath (also known as radial bursa)
    - Encompasses FPL tendon from just proximal to carpal tunnel to its insertion (distal phalanx of thumb)
    - Radial bursa occasionally communicates with ulnar bursa (common flexor sheath) at level of carpal tunnel
- Extensor expansion
  - Formed by fibers from AP on ulnar side and APB on radial side
  - Aids extension of interphalangeal joint
  - AP contribution to extensor expansion is also known as adductor aponeurosis

Tendon Pulley System

- More variable than finger tendon pulley system
- In addition to standard A1 and A2 pulleys, have variable (Av) and oblique pulleys
- A1 pulley: At MCP joint level
- Av pulley : Along proximal 1/2 of proximal phalanx, variable in position, runs either obliquely or transversely across proximal phalanx
- Oblique pulley: Runs obliquely just proximal to A2 pulley
- A2 pulley: At interphalangeal joint level

IMAGING ANATOMY

Overview

- On dorsal transverse imaging, extensor expansions are seen as thin, regular, hypoechoic bands arising from edges of extensor tendon
- On palmar transverse imaging, annular pulleys are seen as thin ring-shaped structures covering flexor tendons and inserting in palmar plate

ANATOMY IMAGING ISSUES

Imaging Recommendations

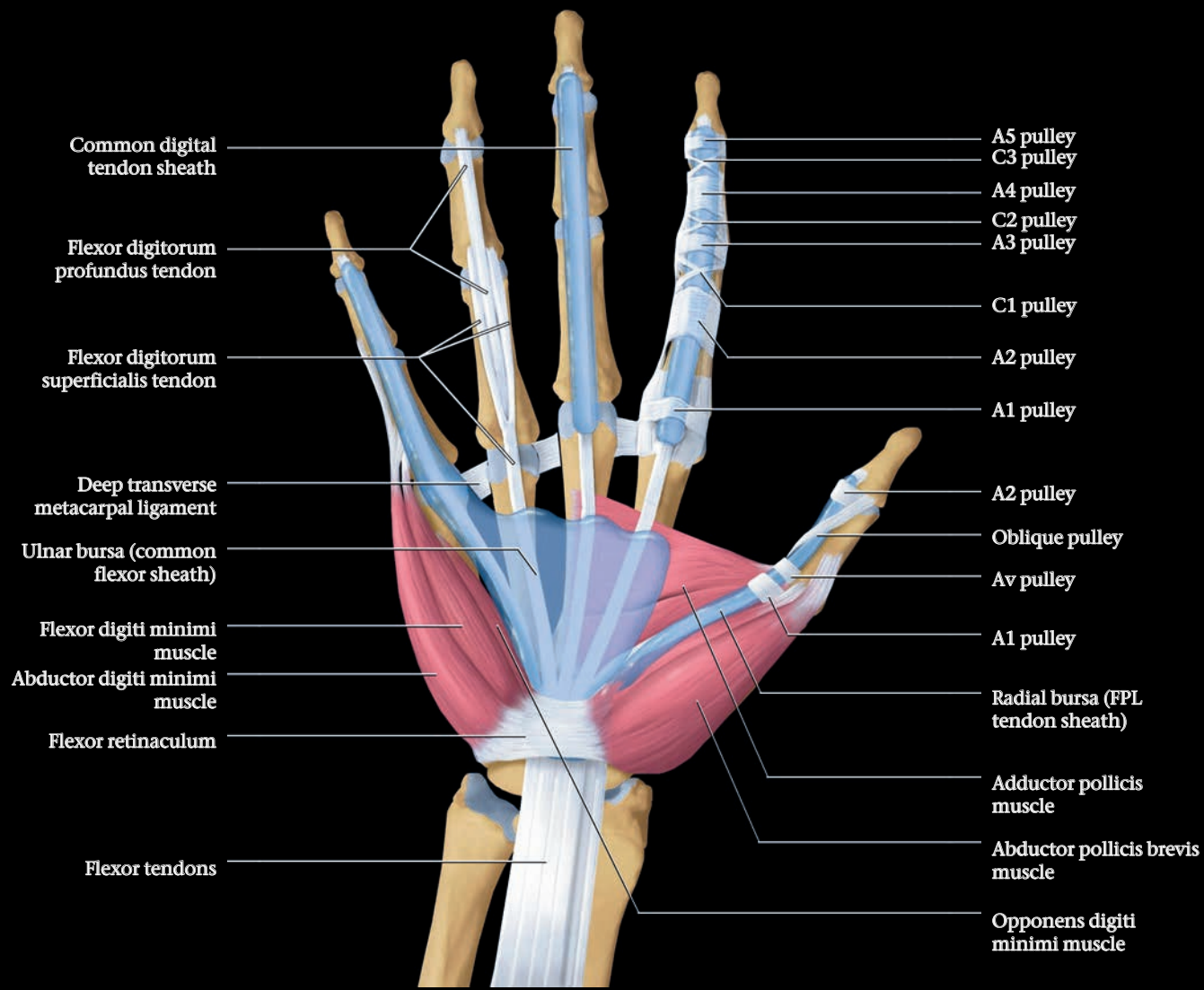
- Thenar muscles can be identified reliably on ultrasound
  - All thenar muscles can be identified by placing transducer in orthograde position, parallel to direction of muscle fibers
- Extensor and flexor tendons of thumb bear similar ultrasound features to other flexor and extensor tendons of hand

CLINICAL IMPLICATIONS

Clinical Importance

- Radial bursa may communicate with ulnar bursa at level of carpal tunnel, allowing spread of infection
- Ulnar collateral ligament of MCP joint of thumb is especially prone to tearing in forced abduction and extension
  - Referred to as gamekeeper's thumb or skier's thumb
  - If ulnar collateral ligament is torn, position of its proximal free end with respect to adductor aponeurosis is of importance
    - If proximal portion is displaced superficial to adductor aponeurosis, it is referred to as Stener lesion, and surgery is usually required
    - Stener lesion: Interposition of adductor aponeurosis between proximally retracted torn ulnar collateral ligament and distal portion
    - If proximal portion remains deep to adductor aponeurosis, conservative management may suffice
- A1 pulley implicated in pathogenesis of trigger thumb
  - Normal thickness of A1 pulley < 0.5 mm
  - In trigger thumb, A1 pulley is thickened to ~ 1 mm or greater
  - ± restricted movement of FPL tendon under A1 pulley during passive flexion on real-time US imaging

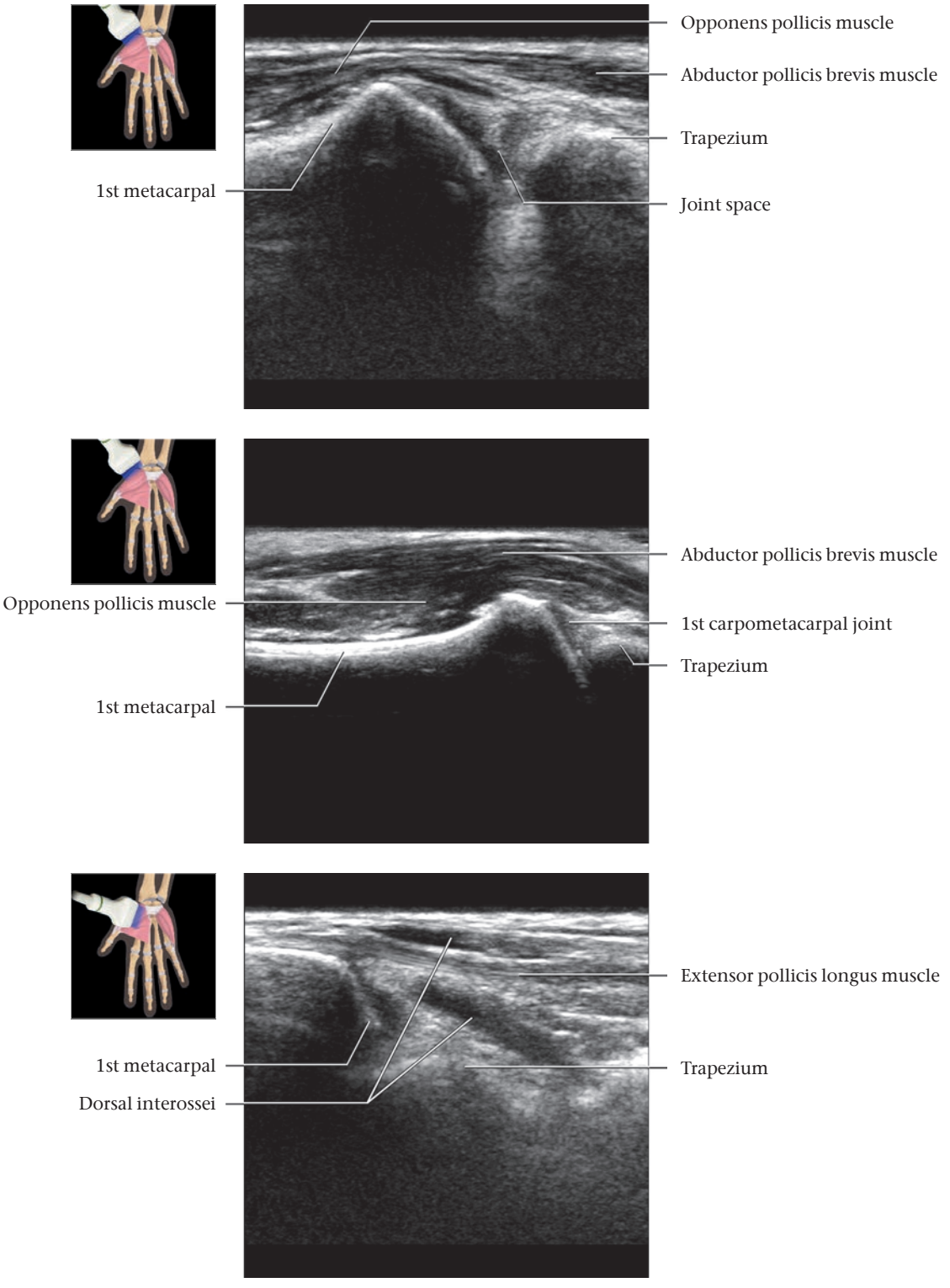
GRAPHIC, DEEP DISSECTION OF HAND



Graphic shows the pulley system of the 2nd digit. The pulley system for 3rd-5th digits, which are identical to that demonstrated for 2nd digit, are removed in this graphic. The common digital sheath of the 4th digit is removed to show the relationship of the flexor digitorum superficialis (FDS) and flexor digitorum profundus (FDP) tendons. Deep transverse metacarpal ligaments connect volar plates (not shown) of digits 2-5. Although there is overlap of radial and ulnar bursae in this image, these structures normally do not communicate. It is, however, important to know that radial and ulnar bursae may communicate as a normal variation in a small percentage of population. Similarly, 1 or more of common digital sheaths may communicate with radial bursa in up to 10% of the normal population. These normal variant bursal communications are important as they can provide routes for more extensive spread of infection.

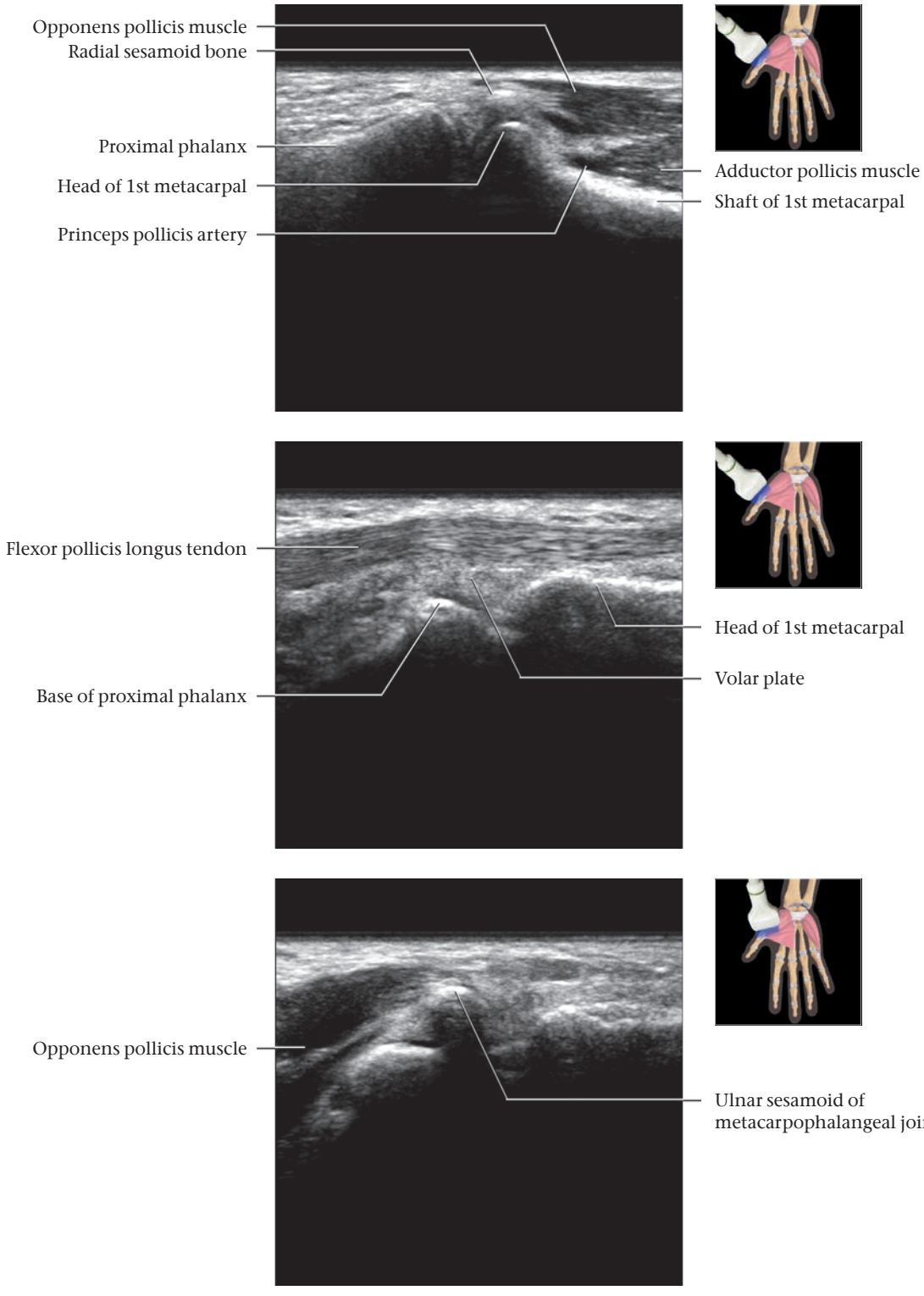
THUMB

US, CARPOMETACARPAL JOINT



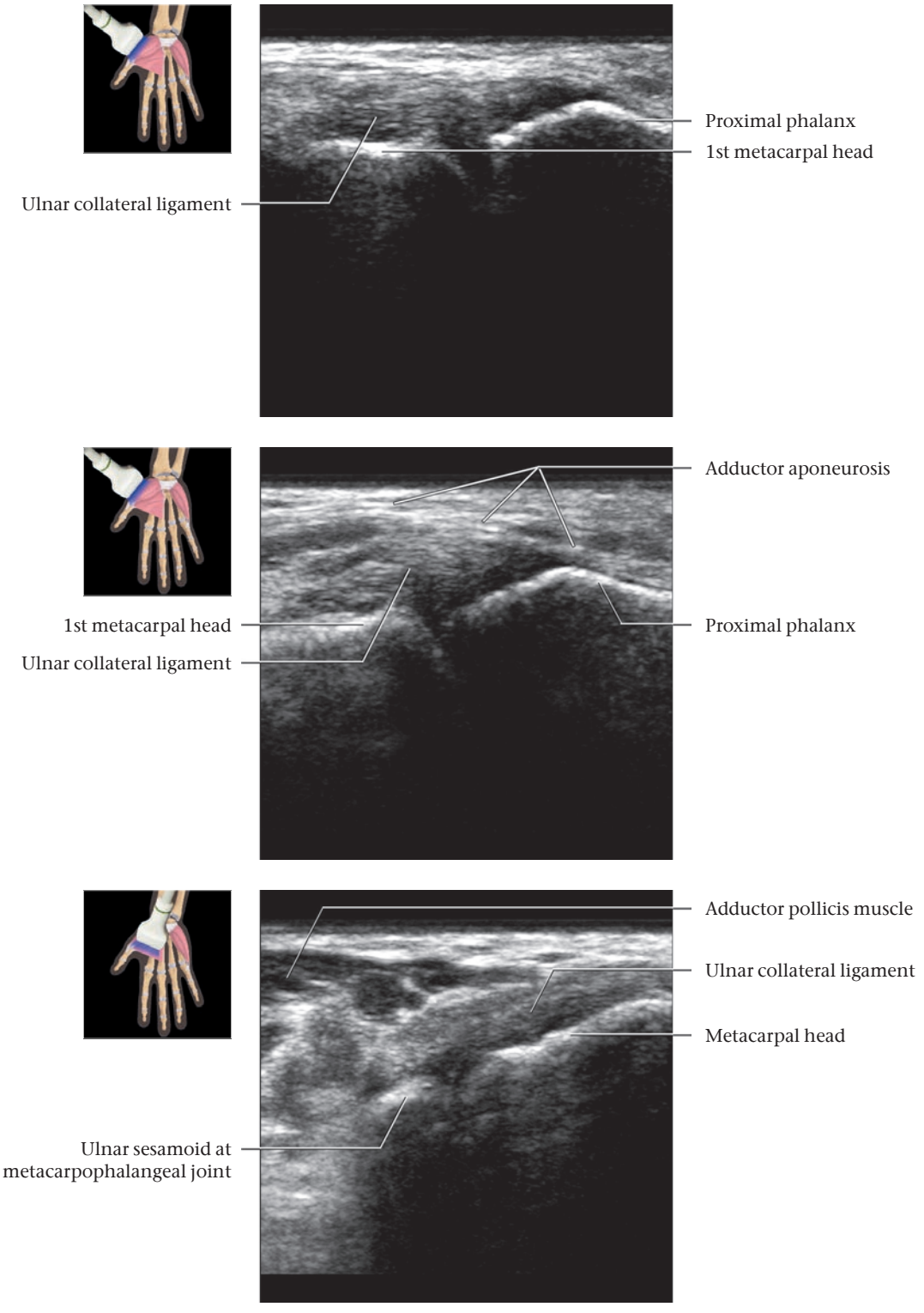
(Top) *Longitudinal grayscale ultrasound shows the palmar aspect of the carpometacarpal joint with radial deviation of the thumb. The carpometacarpal joint of the thumb is by far the most mobile of the carpometacarpal joints. It is best viewed by radially deviating the thumb.* ***(Middle)*** *Longitudinal grayscale ultrasound shows the palmar aspect of the carpometacarpal joint of the thumb. Because of its mobility, the carpometacarpal joint of the thumb is the only carpometacarpal joint prone to osteoarthritis. This gives rise to deep pain in the thenar eminence.* ***(Bottom)*** *Longitudinal grayscale ultrasound shows the dorsal aspect of the carpometacarpal joint of the thumb. The large dorsal component of the 1st metacarpal base relative to the articulating surface on the trapezium leads to a normal step-off on the dorsal aspect of this joint.*

US, METACARPOPHALANGEAL JOINT



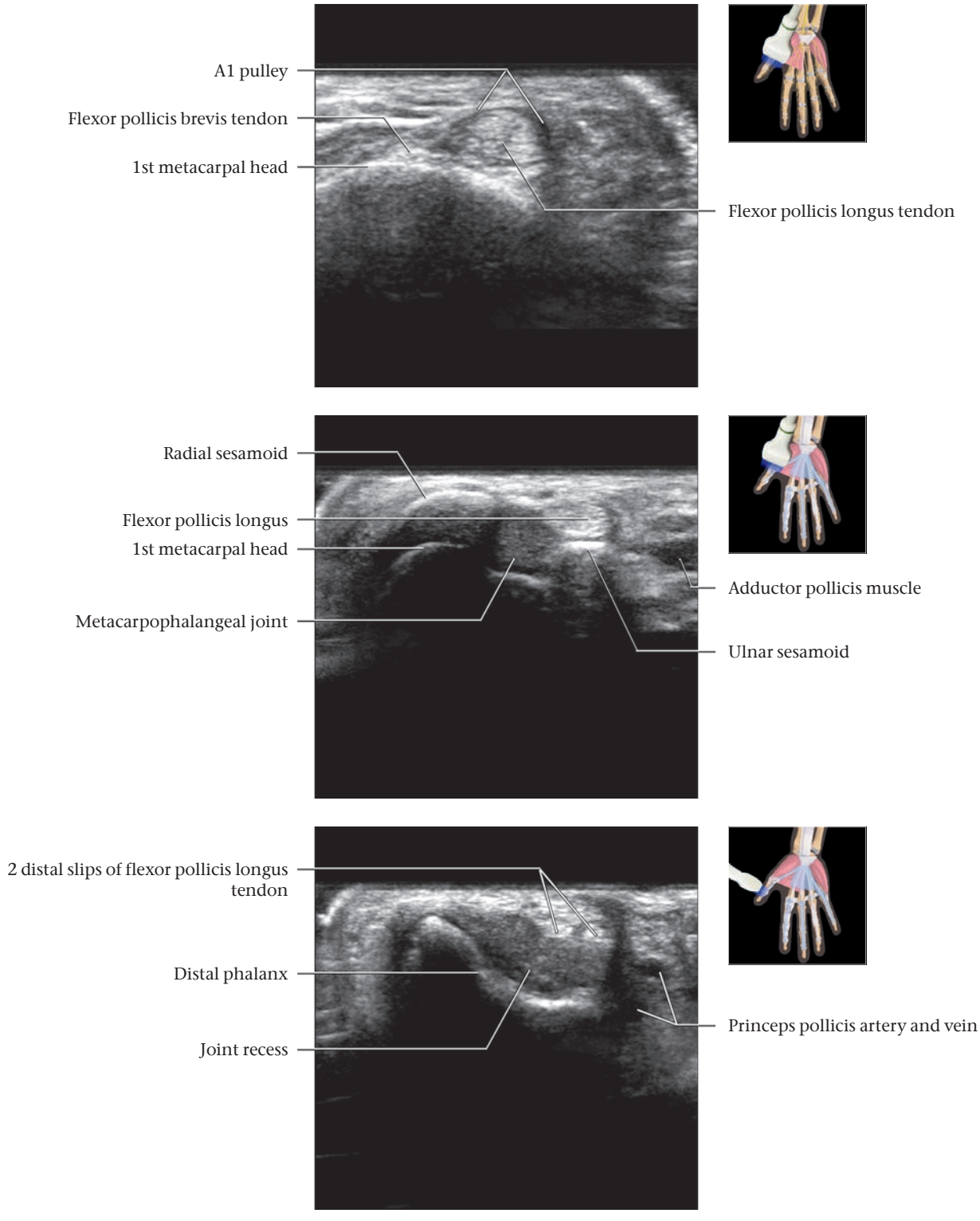
(Top) *Longitudinal grayscale ultrasound shows the metacarpophalangeal joint of the thumb. The collateral ligament complex makes up most of the lateral aspects of the metacarpophalangeal and interphalangeal joint capsules. The ulnar collateral ligament of the 1st metacarpophalangeal joint is especially prone to tearing during forced abduction and extension. Such an injury is commonly referred to as gamekeeper's thumb or skier's thumb.* ***(Middle)*** *Longitudinal grayscale ultrasound shows the metacarpophalangeal joint of the thumb. The volar plate constitutes the majority of the volar aspect of the joint capsule of the metacarpophalangeal joint. The volar plate may be avulsed with forced extension.* ***(Bottom)*** *Transverse grayscale ultrasound shows the 1st metacarpophalangeal joint. The metacarpal head is usually involved in erosions before the proximal phalanx. The metacarpophalangeal joint is an area prone to erosions in inflammatory arthritis.*

ULNAR COLLATERAL LIGAMENT, THUMB



(Top) *Longitudinal grayscale ultrasound along the palmar aspect of the ulnar collateral ligament of the thumb is shown. The ulnar collateral ligament of the metacarpophalangeal joint is commonly injured by forced abduction of the thumb. Avulsion normally occurs at the distal (i.e., proximal phalangeal) attachment.* ***(Middle)*** *Longitudinal grayscale ultrasound shows the ulnar collateral ligament at the midportion. The adductor pollicis aponeurosis overlies the ulnar collateral ligament. The thin adductor aponeurosis is attached to the medial side of the proximal phalanx base and the ulnar sesamoid bone. If the torn ulnar collateral ligament displaces above the adductor aponeurosis (Stener lesion), this is an indication for operative repair.* ***(Bottom)*** *Transverse grayscale ultrasound shows the metacarpophalangeal joint of the thumb. This shows the normal thick ulnar collateral ligament in transverse section.*

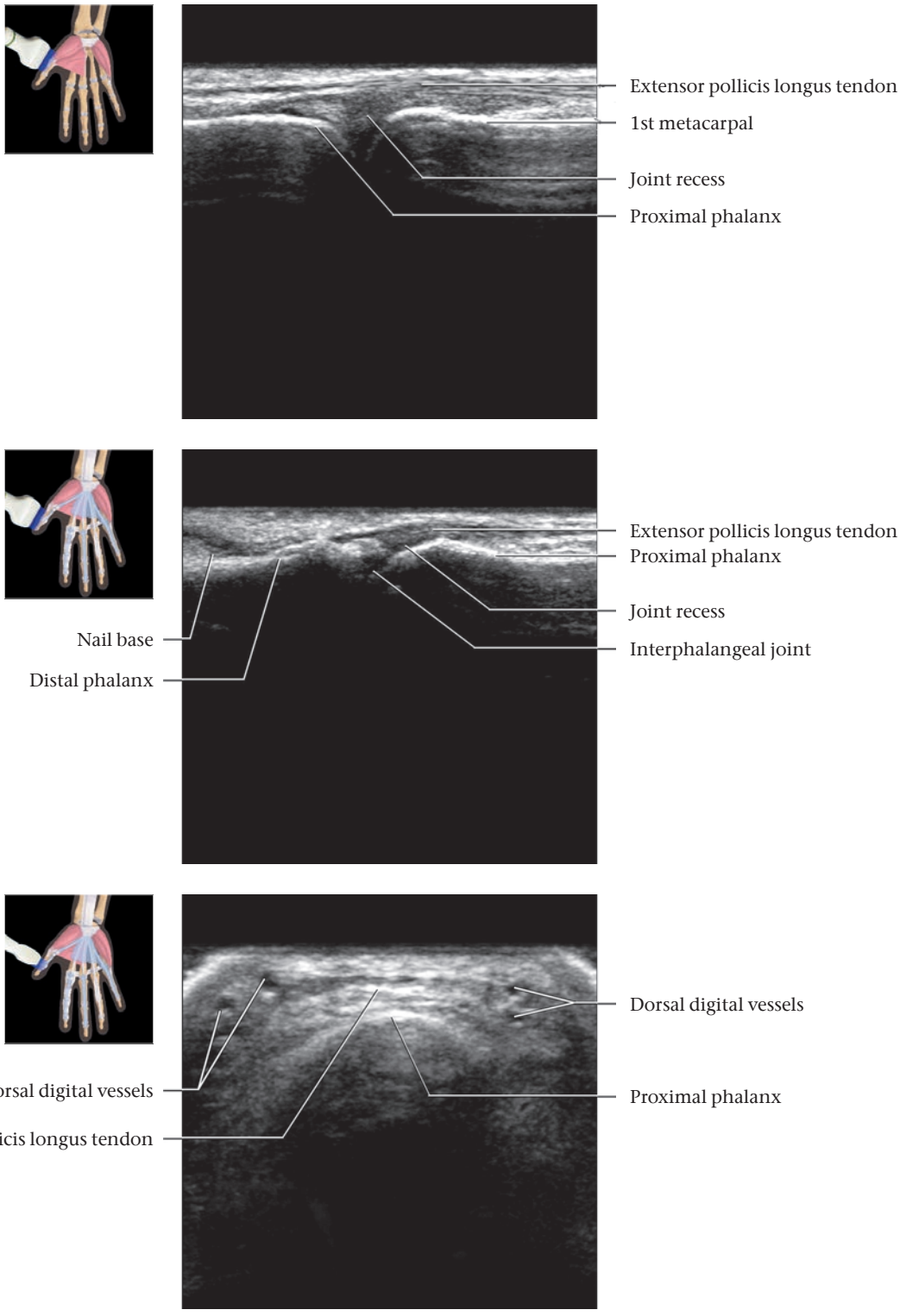
TRANSVERSE US PALMAR ASPECT, THUMB



(Top) *Transverse grayscale ultrasound along the flexor aspect of the thumb at the metacarpal head level is shown. The flexor pollicis brevis inserts into the radial sesamoid and the base of the proximal phalanx. The flexor pollicis longus inserts into the base of the distal phalanx.* ***(Middle)*** *Transverse grayscale ultrasound along the flexor aspect of the thumb at the metacarpophalangeal joint level is shown. The flexor pollicis longus tendon passes over the ulnar sesamoid bone of the metacarpophalangeal joint.* ***(Bottom)*** *Transverse grayscale ultrasound along the flexor aspect of the thumb at the interphalangeal joint level is shown. The flexor pollicis longus tendon is held in position primarily by the A1 pulley at the metacarpophalangeal joint and the A2 pulley at the interphalangeal joint. The flexor pollicis longus tendon may divide into 2 slips at its insertion.*

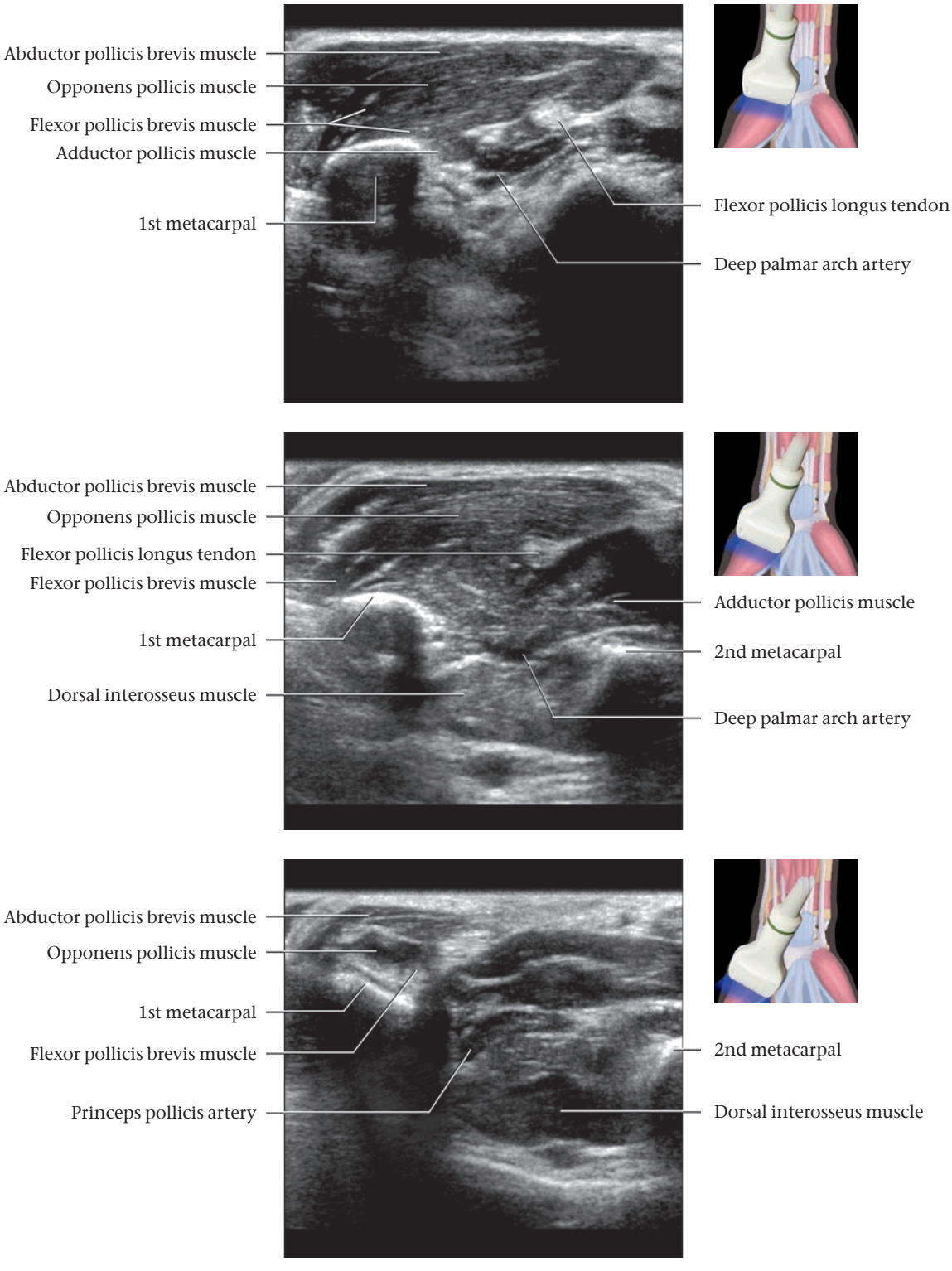
THUMB

EXTENSOR ASPECT, THUMB



(Top) *Longitudinal grayscale ultrasound along the extensor aspect of the thumb at the metacarpophalangeal joint level is shown. The extensor pollicis longus tendon thins as it merges with the extensor expansion on the dorsum of the thumb.* ***(Middle)*** *Longitudinal grayscale ultrasound along the extensor aspect of the thumb at the interphalangeal joint level is shown. The extensor pollicis longus tendon inserts into the distal phalanx.* ***(Bottom)*** *Transverse grayscale ultrasound along the extensor aspect of the thumb at the proximal phalanx level is shown. The thin extensor expansion of the extensor pollicis longus is visible.*

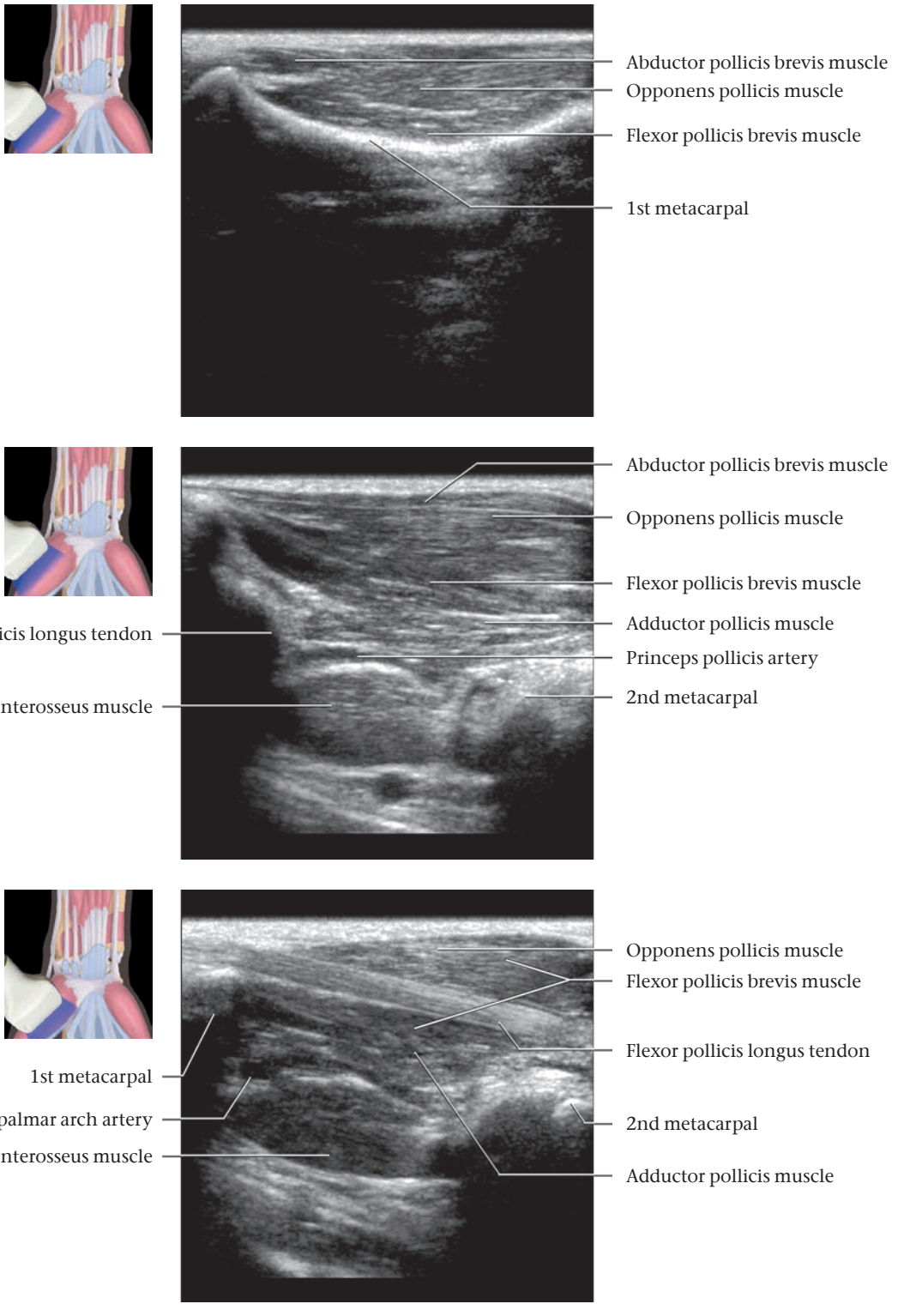
TRANSVERSE US, THENAR EMINENCE



(Top) *Transverse grayscale ultrasound along the proximal aspect of the thenar eminence is shown. The thenar eminence is composed of 4 muscles: The abductor, opponens, flexor, and adductor pollicis from superficial to deep. The adductor muscle is, strictly speaking, not part of the thenar eminence since it is separated by a fascial layer and has a separate innervation.* ***(Middle)*** *Transverse grayscale ultrasound shows the midportion of the thenar eminence. The flexor pollicis longus tendon is easily recognized as an echogenic tendon alongside the flexor pollicis brevis, deep to the opponens pollicis and superficial to the adductor pollicis muscle.* ***(Bottom)*** *Transverse grayscale ultrasound shows the distal portion of the thenar eminence.*

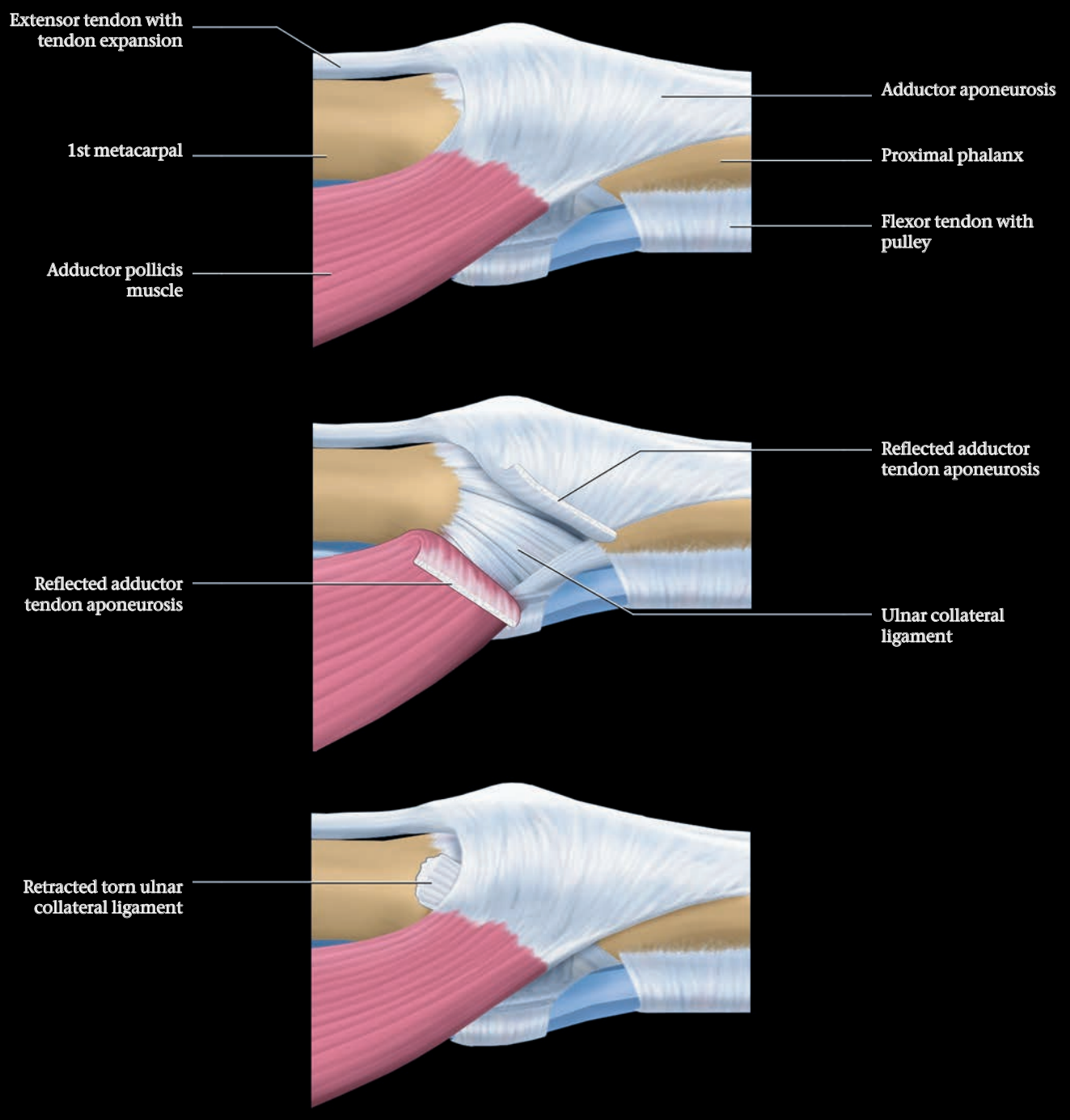
THUMB

LONGITUDINAL US, THENAR EMINENCE



(Top) *Longitudinal grayscale ultrasound along the proximal aspect of thenar eminence is shown. Use the mnemonic ABOF to remember the muscles of the thenar eminence.* ***(Middle)*** *Longitudinal grayscale ultrasound shows the midthenar eminence. ABOF stands for abductor pollicis brevis, opponens pollicis, and flexor pollicis brevis, which lie superficial to deep in that order. Abductor pollicis brevis and flexor pollicis brevis share a combined insertion at the lateral base of the proximal phalanx of the 1st digit.* ***(Bottom)*** *Longitudinal grayscale ultrasound along the ulnar aspect of the thenar eminence is shown. Although often grouped with the thenar muscles due to proximity, the adductor pollicis is distinct from them, as it is separated from the thenar muscles by a fascial plane and innervated by the ulnar nerve as opposed to the median nerve.*

GRAPHICS, STENER LESION



Graphic shows the ulnar aspect of the metacarpophalangeal joint of the thumb. On the top image, the adductor tendon aponeurosis attaches to the extensor expansion on the dorsum of the thumb. The middle image shows a reflected adductor aponeurosis with the ulnar collateral ligament beneath. When a complete tear of the ulnar collateral ligament occurs, shown in the bottom image, the proximal end of the ligament may be retracted back over the adductor aponeurosis. This is referred to as a Stener lesion and does require surgical intervention.

FINGERS

TERMINOLOGY

Abbreviations

- Extensor digitorum communis (EDC)
- Extensor digiti minimi (EDM)
- Interphalangeal (IP) joint
- Metacarpophalangeal joint (MCP) joint

GROSS ANATOMY

Muscles

- Flexor aspect
  - Flexor digitorum superficialis (FDS)
    - Origin: Common flexor tendon origin and midradius
    - Insertion: Volar plates of proximal IP joints and bases of middle phalanges digits 2-5
    - Superficialis tendon is superficial to profundus tendon in palm until it divides at level of proximal 1/3 of proximal phalanx
    - 2 slips of superficialis tendon pass around profundus tendon and reunite deep to profundus tendon prior to insertion
    - Flexes both MCP joints, aided by lumbricals and interossei and proximal IP joints of digits 2-5
  - Flexor digitorum profundus (FDP)
    - Origin: Proximal radius, midradius, and interosseus membrane
    - Profundus tendon passes through divided superficialis tendon to insert at base of distal phalanx
    - Insertion: Volar plates of distal IP joints and bases of distal phalanges digits 2-5
    - Flexes distal and proximal IP joints as well as MCP joints aided by lumbricals and interossei
- Palmar interossei
  - Denoted 1-3 from radial to ulnar
  - Origin: Mesial palmar diaphyses of 2nd, 4th, and 5th metacarpals
  - Insertion: Mesial lateral bands and proximal phalanges have same base as digit of origin
  - Adducts digits and assists lumbricals with flexion MCP and extension IP joints in digits 2, 4, and 5
- Extensor aspect
  - EDC
    - Origin: Common extensor tendon origin (lateral humeral epicondyle)
    - Insertion: As central slip at bases of middle phalanges and proximal IP joint capsule
    - Separate EDC tendon to 5th digit tendon is present in 50% of general population
  - Extensor indicis
    - Origin: Posterior ulna, distal ulna, and interosseus membrane
    - Insertion: Blends with 2nd digit EDC tendon and extensor hood
  - EDM
    - Origin: Common extensor tendon origin (lateral humeral epicondyle)
    - Insertion: 2 tendons of EDM fuse with one another and with 5th digit EDC tendon prior to insertion at base of proximal phalanx 5th digit
- Lumbricals
  - Numbered 1-4 from radial to ulnar
  - Origin: FDP tendons, just distal to carpal tunnel
  - Insertion: Radial lateral bands of digits 2-5
    - Extend IP and flex MCP joints of digits 2-5
- Dorsal interossei
  - Numbered 1-4 from radial to ulnar
  - Origin: Dorsolateral metacarpal diaphyses
  - Insertion: Adjacent lateral bands of digits 2-4
    - Extend 2nd-5th IP joints and abduct digits 2-5

Tendon Pulley System

- Annular pulley
  - Retinaculum that retain flexor tendons at 5 points = annular pulleys
  - Prevent tendon bowstringing during finger flexion
  - **Odd** numbered pulleys at **oval** parts (i.e., joints)
  - **Even** numbered pulleys at **elegant** waists (i.e., shafts)
  - A2 and A4 are functionally the most important pulleys to prevent bowstringing
    - A1: MCP joint and base of proximal phalanx
    - A2: Middle and distal 3rds of proximal phalanx
    - A3: Proximal interphalangeal joint
    - A4: Midshaft of middle phalanx
    - A5: Distal interphalangeal joint
  - Also cruciform pulleys, C1-C3
- Extensor expansion
  - Begins just proximal to MCP joints and terminates just proximal to proximal IP joint
  - Dorsal expansion of fibers oriented perpendicular to long axis of extensor tendons
  - Fibers of extensor expansion interdigitate with EDC tendons to prevent lateral translation

Tendon Sheaths

- 2nd to 4th flexor synovial sheaths extend from metacarpal neck to bases of distal phalanges
- Different for 5th digit flexor tendons, which are covered by synovial sheath over their entire course (to level of distal IP joint)

ANATOMY IMAGING ISSUES

Imaging Approaches

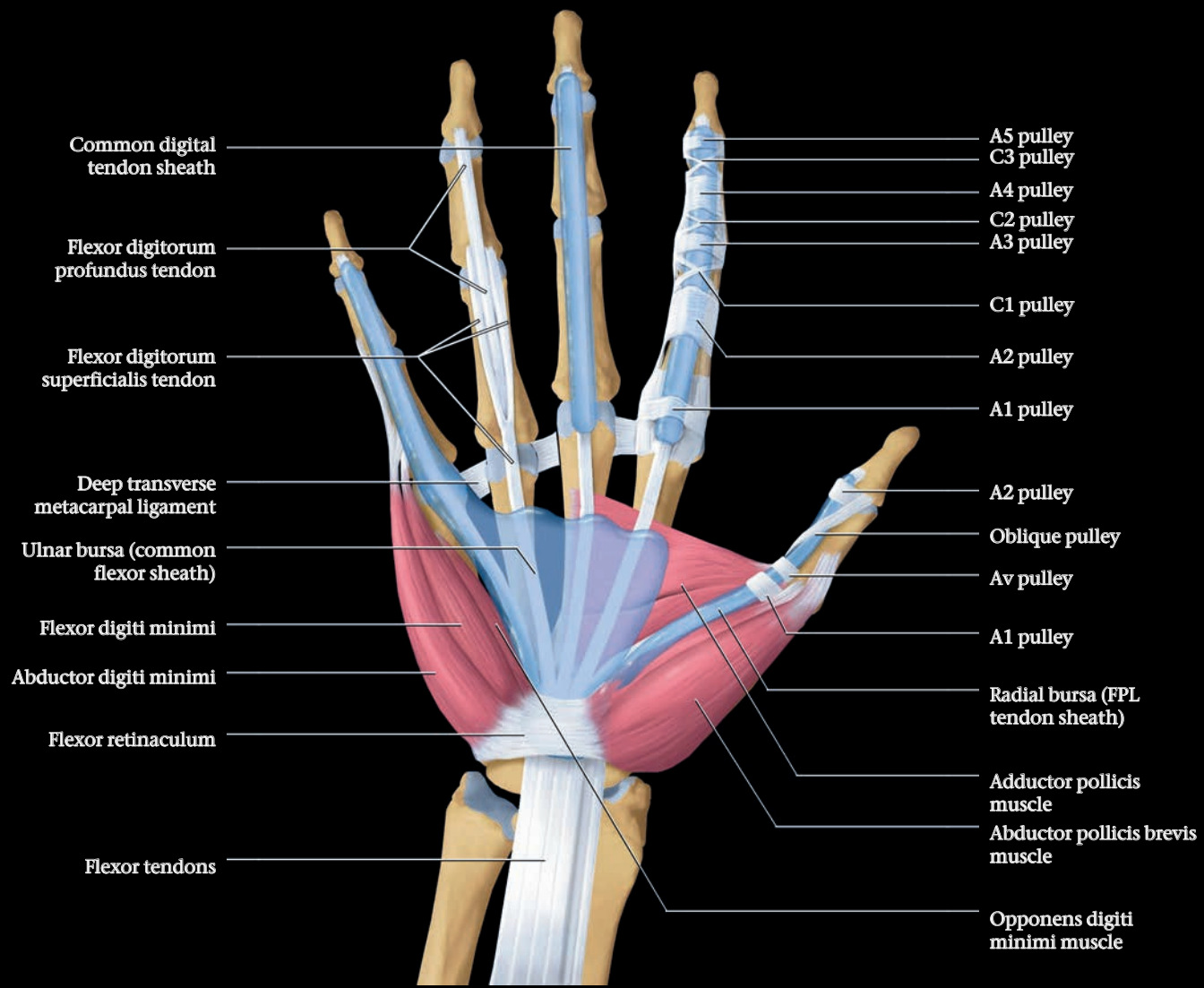
- Extensor tendons in digits often seen best on longitudinal imaging
- Pulleys are seen as focal hypoechoic thickening overlying tendon sheath
  - As pulleys are widened at base, thickness of pulleys should be measured at 10 or 2 o'clock positions
  - Do not misdiagnose as tendon sheath thickening
  - A1 and A2 pulley can be depicted in most cases
  - Injury inferred by bowstringing of flexor tendons
  - Compare with normal fingers

CLINICAL IMPLICATIONS

Clinical Importance

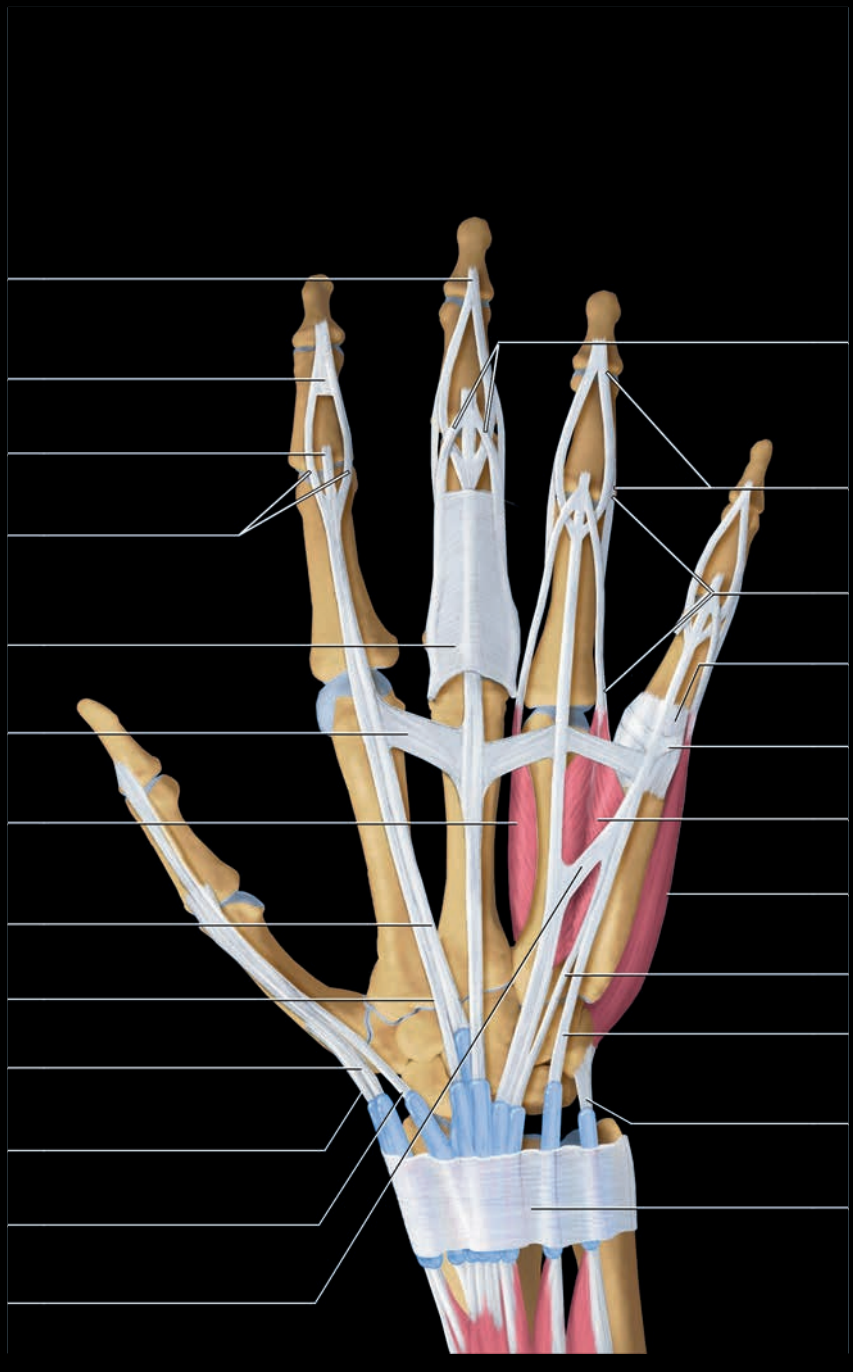
- Digital sheaths may connect to ulnar bursa in up to 10% of population, providing route for spread of infection from digits 2-4 to common flexor sheath and vice versa
- Pulley injury inferred by bowstringing of flexor tendons

GRAPHIC, TENDON SHEATHS



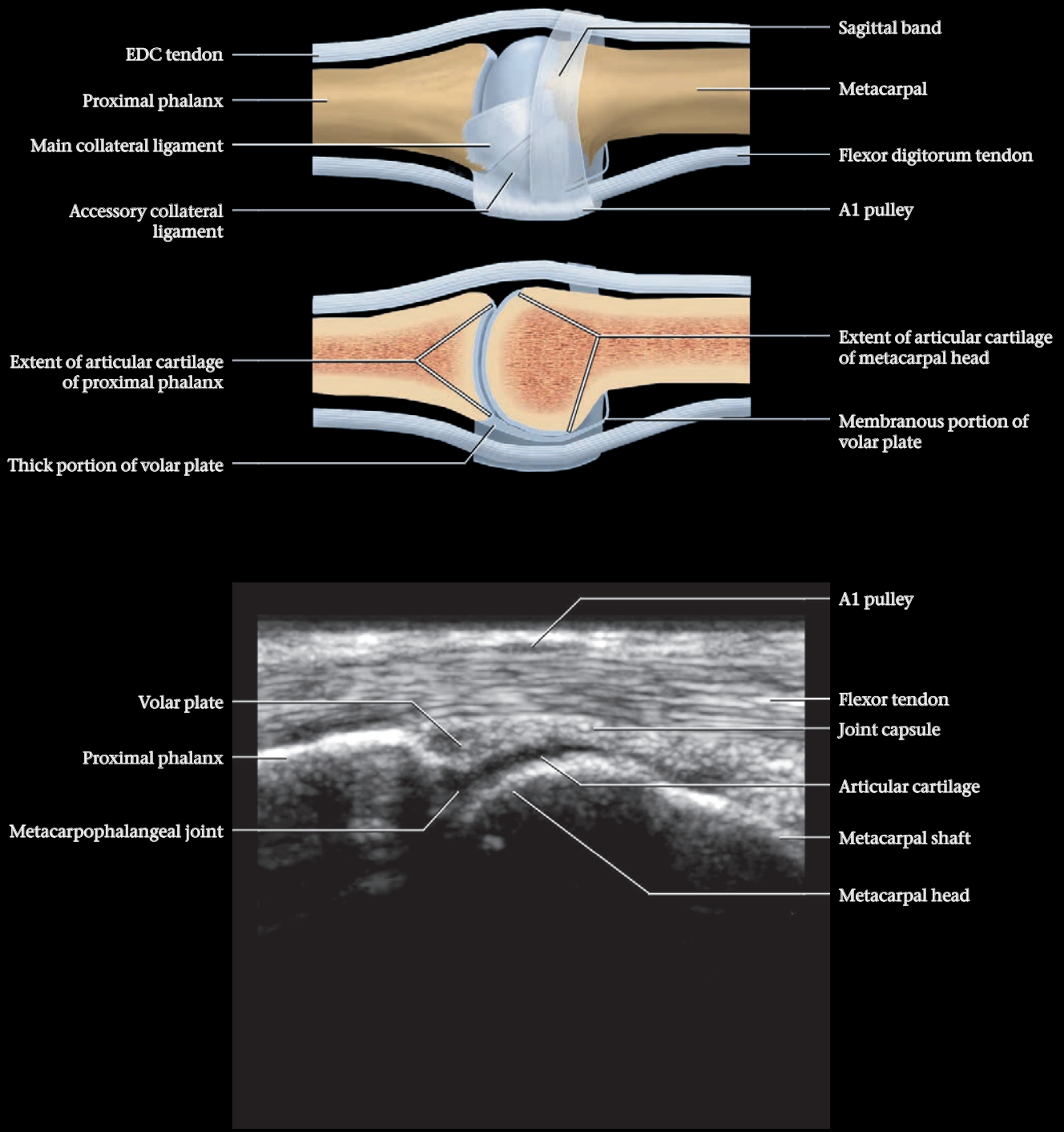
Graphic of pulley system on the palmar side of the 3rd-5th digits is identical to that demonstrated for the 2nd digit. The common digital sheath of the 4th digit is removed to show the relationship of the flexor digitorum superficialis (FDS) and flexor digitorum profundus (FDP) tendons. Deep transverse metacarpal ligaments connect the volar plates (not shown) of digits 2-5. Although there is overlap of the radial and ulnar bursae in this image, these structures normally do not communicate. It is, however, important to know that the radial and ulnar bursae may communicate as a normal variation in a small percentage of the population. Similarly, any one or more of the digital sheaths may communicate with the radial bursa in up to 10% of the normal population. These normal variant bursal communications are important as they can provide routes for more extensive spread of infection.

GRAPHIC, LIGAMENTS AND PULLEYS



Graphic of the dorsum hand and finger extensor mechanism shows different components of the extensor mechanism on different digits. With the exception of the extensor indicis, extensor digiti minimi, abductor digiti minimi, and 4th extensor digitorum communis (EDC) tendon contribution to the 5th EDC tendon, any structure on any of the 2nd-5th digits can be extrapolated to any and all of the other 2nd-5th digits. Note that the 2nd extensor retinaculum compartment and its contents (extensor carpi radialis longus and brevis tendons) are not included in this graphic. Although the abductor pollicis longus tendon travels in the 1st compartment of the extensor retinaculum, its insertion (not shown) is actually on the radial aspect of the volar surface of the base of the 1st metacarpal.

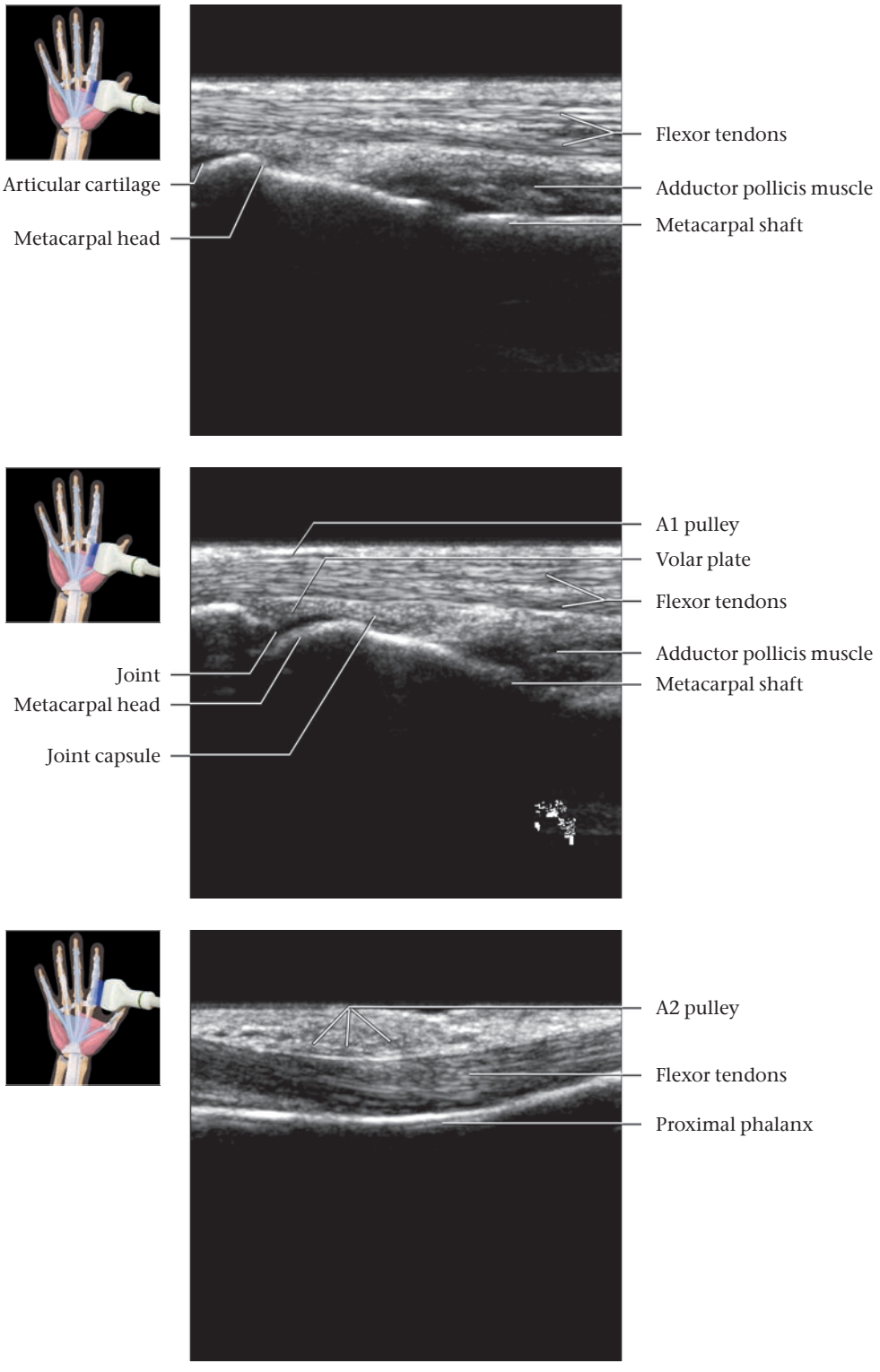
GRAPHIC AND LONGITUDINAL US, METACARPOPHALANGEAL JOINT



(Top) *Surface and cut-section graphics show the metacarpophalangeal (MCP) joint. The collateral ligament complex is composed of 2 separate fiber bands. The main collateral ligament inserts on the base of the adjacent phalanx. The accessory collateral ligament inserts on the volar plate. The volar plate is thick distally and thin and redundant proximally. With the exception of the sagittal band (present only at MCP joints), anatomy in this graphic is duplicated in all MCP and interphalangeal (IP) joints in the hand.* ***(Bottom)*** *Longitudinal grayscale ultrasound shows the middle finger at the MCP joint.*

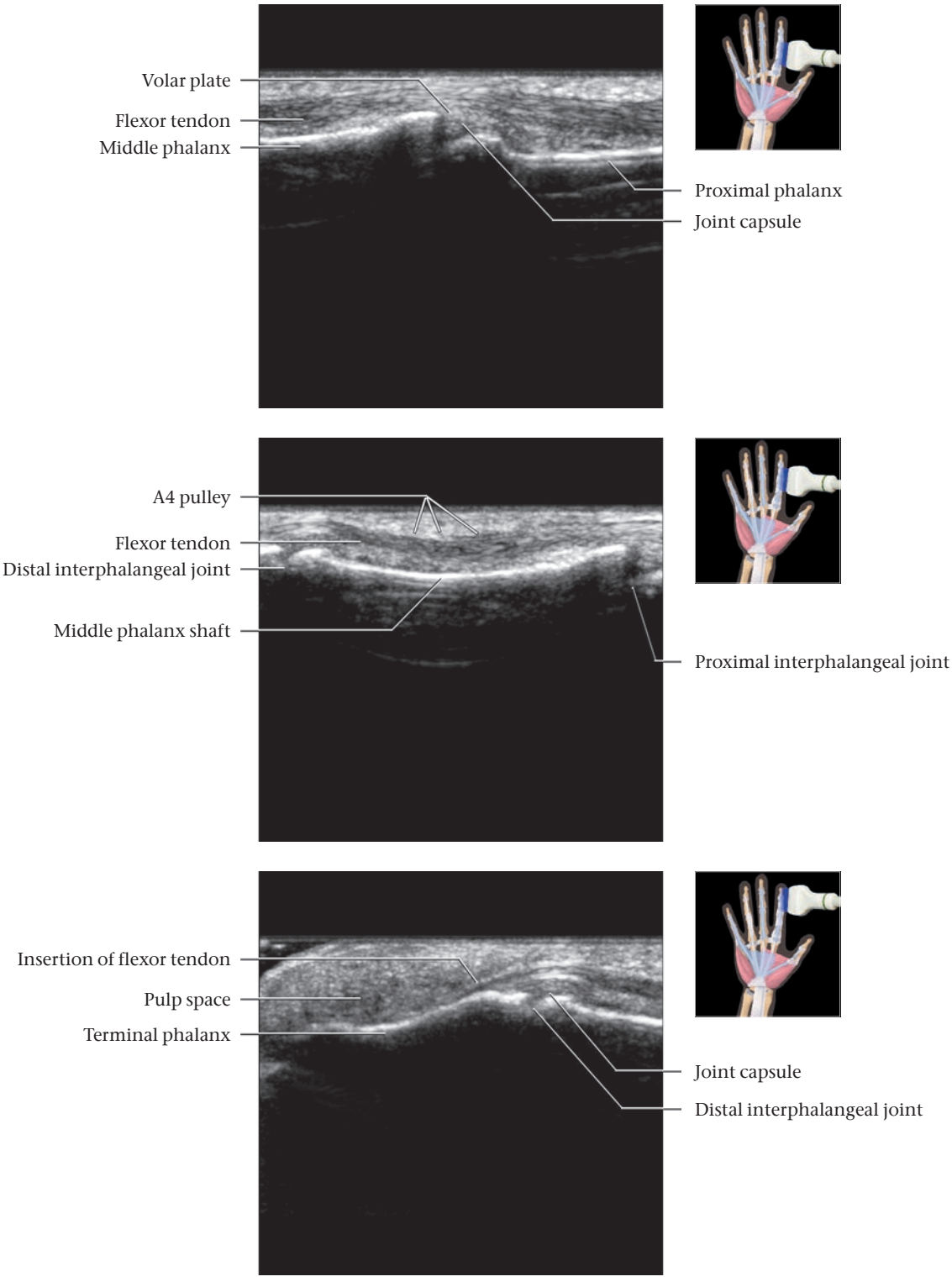
FINGERS

LONGITUDINAL US



(Top) *Longitudinal grayscale US shows the finger at the metacarpal shaft level. From the base of the metacarpals (carpal tunnel outlet) to the neck of the metacarpals, the flexor tendons of the 2nd-4th fingers (i.e., index, middle, and ring fingers) are devoid of flexor tendon sheaths. A normal flexor tendon sheath cannot be seen on ultrasound and can only be seen when it is distended. Do not confuse the flexor tendon pulleys with tendon sheath thickening.* ***(Middle)*** *Longitudinal grayscale US shows fingers at the MCP joint level. MCP joints are narrowed dorsally and flare in the volar direction, increasing contact with the proximal phalanx as the joint is flexed. The capsule of the MCP joint extends from the metacarpal neck level to the base of proximal phalangeal joint.* ***(Bottom)*** *Longitudinal grayscale US shows the A2 pulley of the middle finger at the proximal phalanx.*

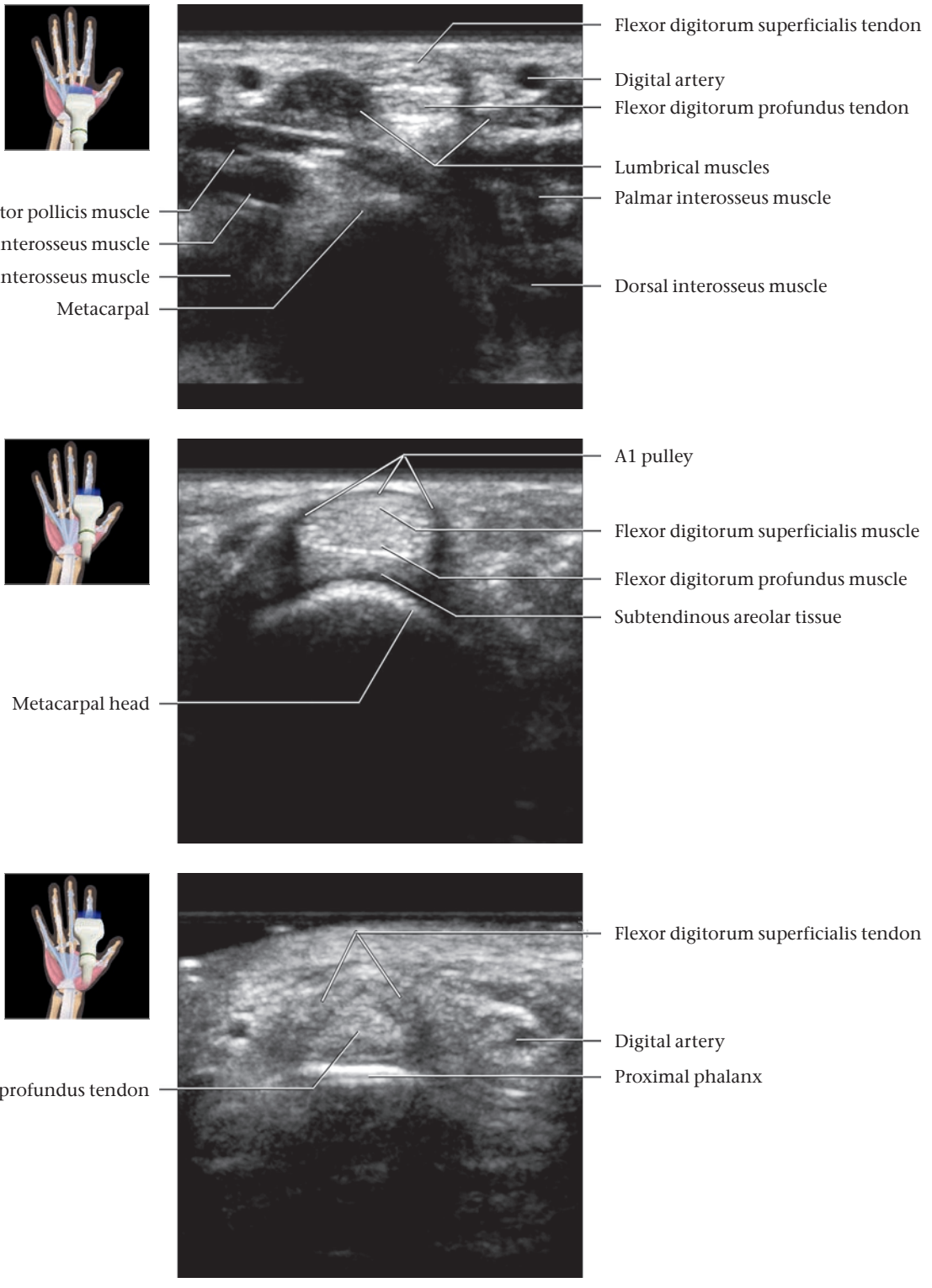
LONGITUDINAL US



(Top) *Longitudinal grayscale US shows the proximal interphalangeal (IP) joint of the middle finger. The volar plate is a fibrocartilaginous thickening on the volar aspect of the MCP joint and proximal IP joints. At the proximal IP joint, it is firmly attached to the base of the middle phalanx and has a thinner insertion onto the distal end of the proximal phalanx. It may become avulsed during hyperextension injuries often associated with a small avulsion fracture. There is an inability to fully extend and flex the joint, a condition that usually improves with time unless the joint is locked.* ***(Middle)*** *Longitudinal grayscale US shows the middle finger at the middle phalanx. The A4 pulley prevents bowstringing of flexor tendons at the middle phalanx.* ***(Bottom)*** *Longitudinal grayscale US shows the distal IP joint of middle finger. An avulsion of the flexor tendon from the distal phalangeal base is usually accompanied by a small avulsion fracture.*

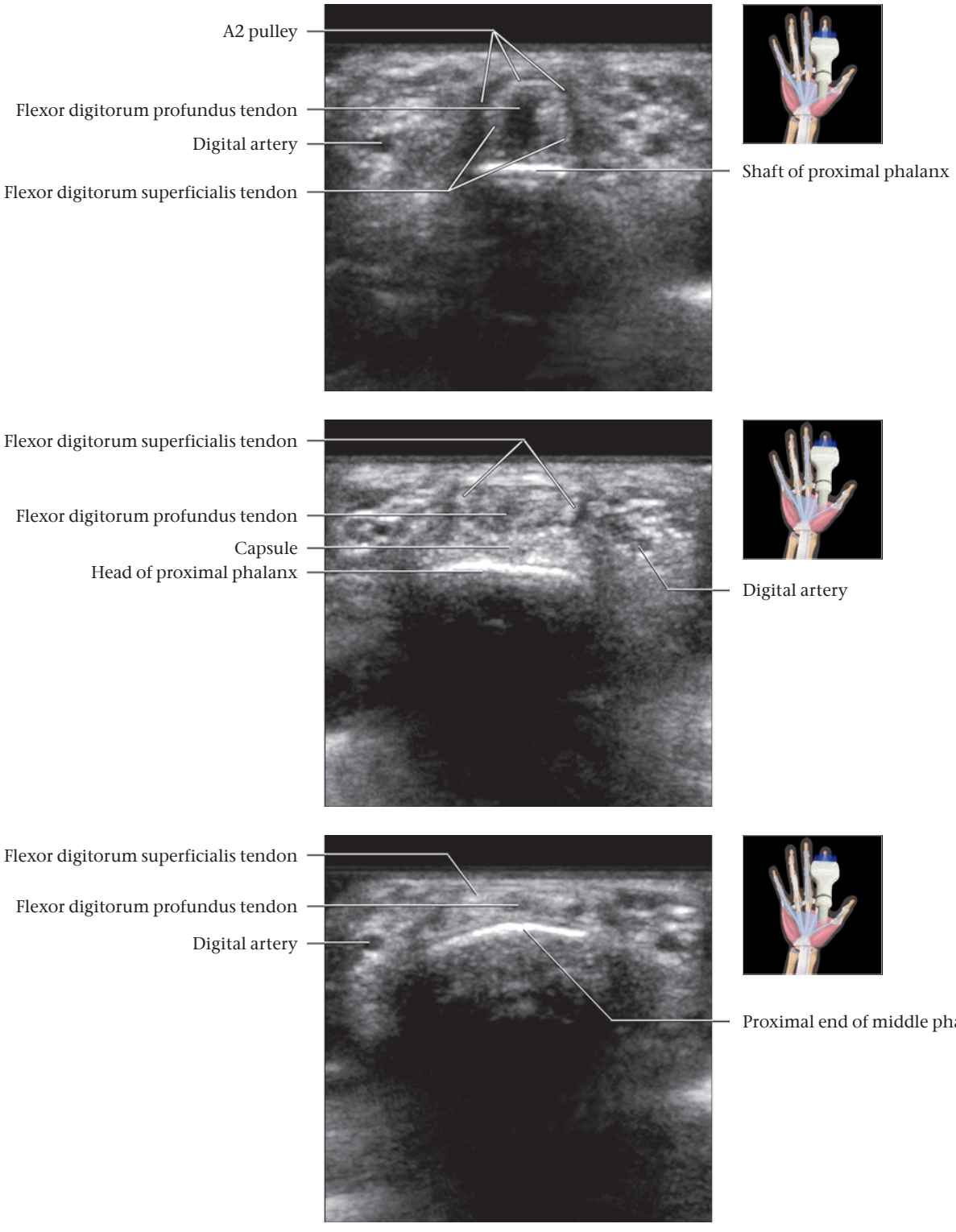
FINGERS

TRANSVERSE US



(Top) *Transverse grayscale US shows the middle finger at the metacarpal shaft. There are 4 lumbrical muscles in the hand. These are unusual muscles in that they do not originate from the skeleton but instead originate from the flexor digitorum tendons and insert into the extensor expansions.* ***(Middle)*** *Transverse grayscale US shows the middle finger at the metacarpal head. This image is of the A1 pulley level. The A1 pulley extends from the metacarpal head to the proximal phalanx base. It is seen as a thin hypoechoic to hyperechoic rim (depending on the beam angulation) around the flexor tendons. It broadens considerably at the base, which cannot be clearly depicted.* ***(Bottom)*** *Transverse grayscale US shows the middle finger at the proximal phalanx. The flexor digitorum superficialis (FDS) tendon splits just proximal to the insertion, enabling the flexor digitorum profundus (FDP) tendon to push through the gap.*

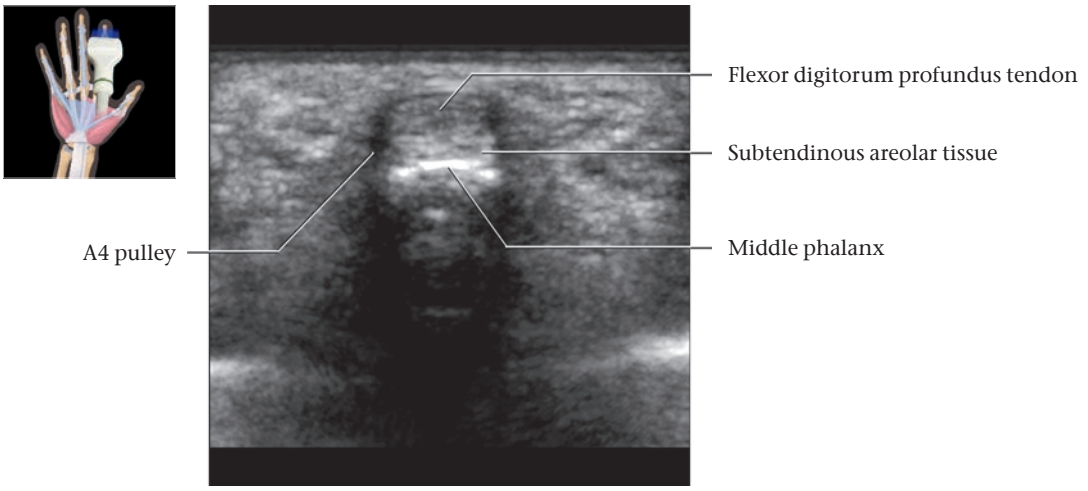
TRANSVERSE US

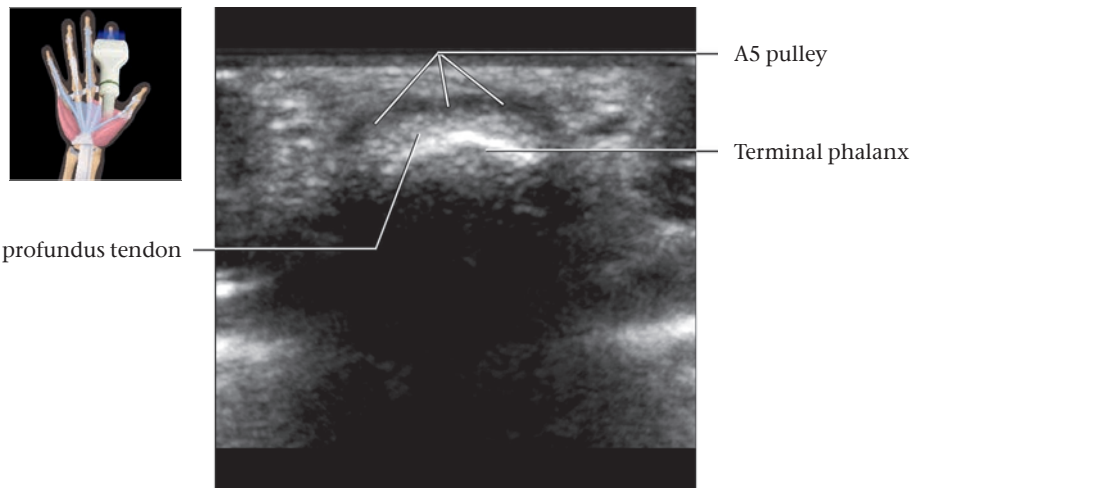


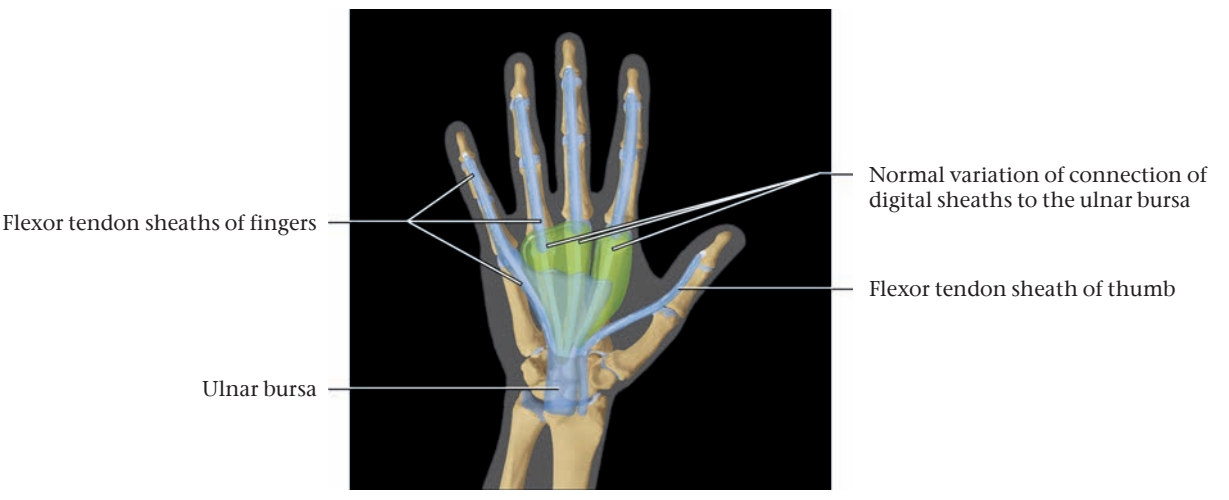
(Top) *Transverse grayscale ultrasound shows the middle finger shaft of the proximal phalanx. Do not confuse thickening of the A2 pulley with tendon sheath thickening.* ***(Middle)*** *Transverse grayscale ultrasound shows the middle finger proximal phalangeal head region just distal to the A2 pulley. The small slips of the flexor digitorum superficialis (FDS) tendon descend on either side of the flexor digitorum profundus (FDP) tendon to insert onto the volar aspect of the base of the middle phalanx.* ***(Bottom)*** *Transverse grayscale ultrasound shows the middle finger at proximal end of the middle phalanx. The insertions of the slips of the FDS are small. As such, particularly in the presence of edema, it may be difficult to confirm isolated avulsion of 1 slip on ultrasound. In this situation, the flexor digitorum superficialis tendon will not be retracted.*

FINGERS

TRANSVERSE US AND GRAPHIC

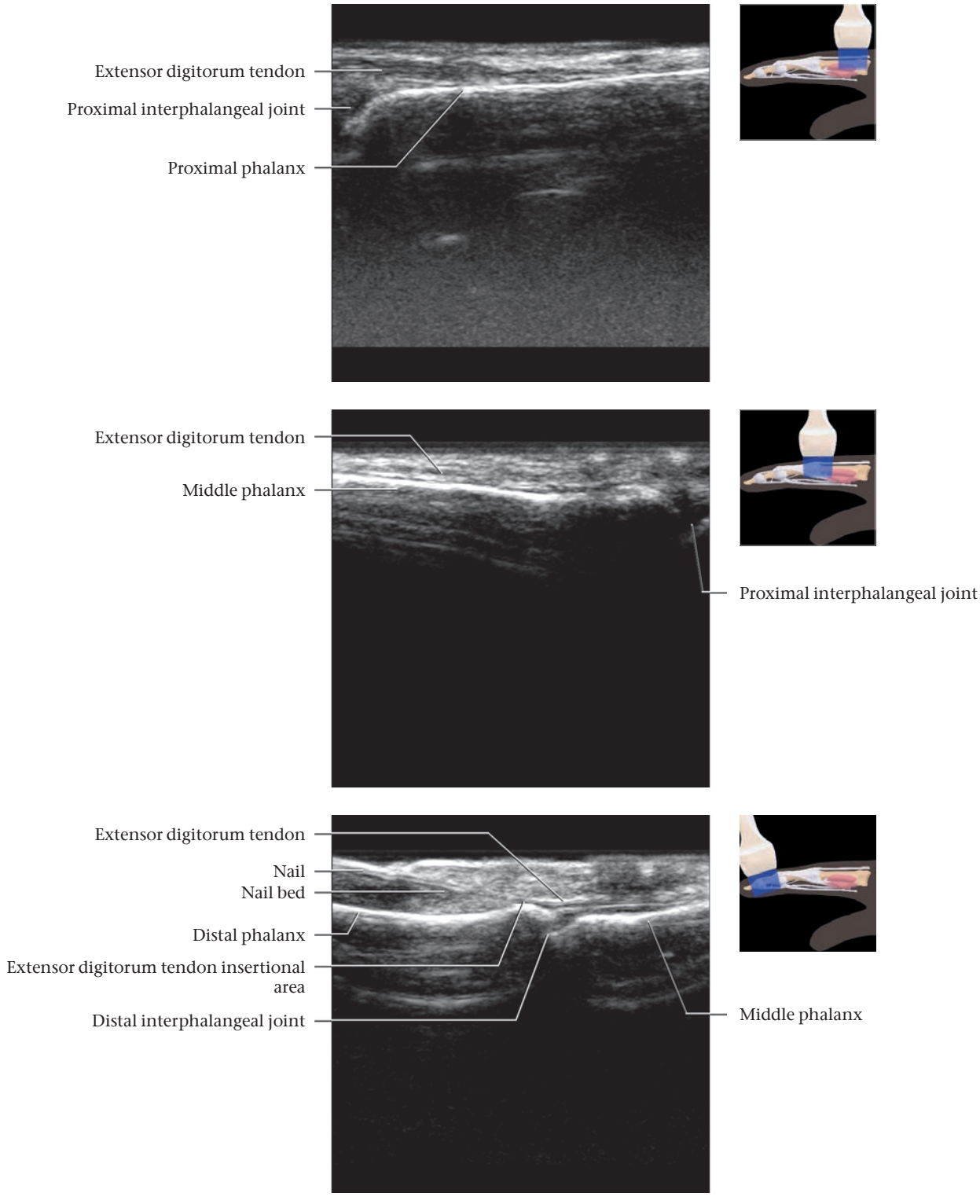






(Top) *Transverse grayscale ultrasound shows the middle finger at the shaft of the middle phalanx. Do not confuse the subtendinous connective tissue as part of the tendon.* ***(Middle)*** *Transverse grayscale ultrasound shows the middle finger at the base of the distal phalanx. The flexor digitorum profundus (FDP) tendon gains broad attachment to the base of the distal phalanx and is supported by the A5 pulley just proximal to the insertion.* ***(Bottom)*** *Graphic shows the tendon sheaths of the fingers (blue). Digital sheaths may connect to the ulnar bursa (green) in up to 10% of the population, providing a route for the spread of infection from digits 2-4 to the common flexor sheath and vice versa.*

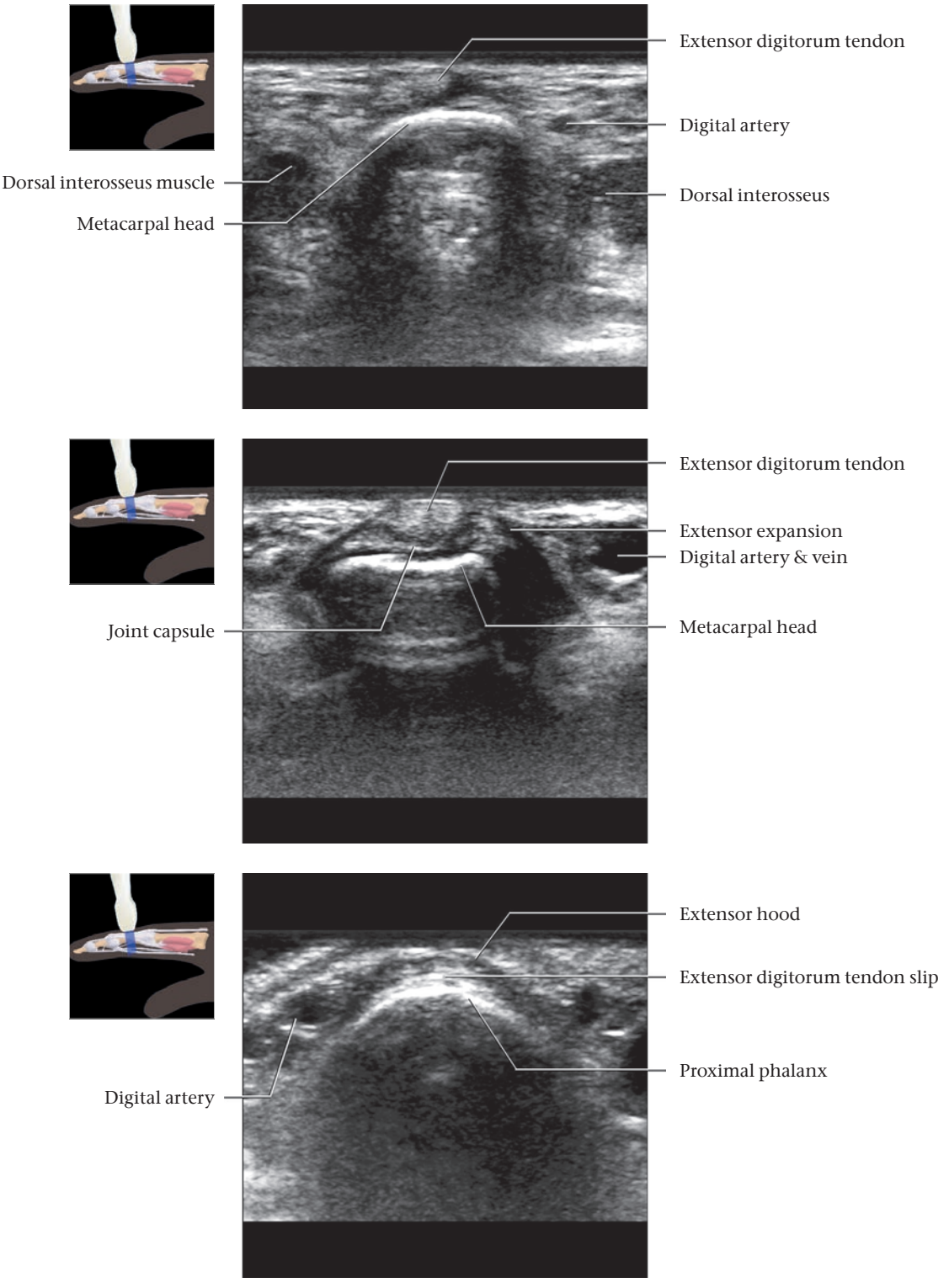
LONGITUDINAL US, EXTENSOR ASPECT



(Top) *Longitudinal grayscale ultrasound shows the dorsal aspect of the proximal phalanx. The extensor expansion on the dorsum of the fingers is thin and flat and does not have a synovial sheath.* ***(Middle)*** *Longitudinal grayscale ultrasound shows the dorsal aspect of the middle phalanx. No pulleys are present on the extensor aspect of the fingers. The extensor expansion (or hood) are attached to the phalanges and the lateral bands.* ***(Bottom)*** *Longitudinal grayscale ultrasound shows the dorsal aspect of the distal phalanx. The extensor digitorum is attached to the base of the distal phalanx. This is a common site of avulsion, often with a small avulsion fracture.*

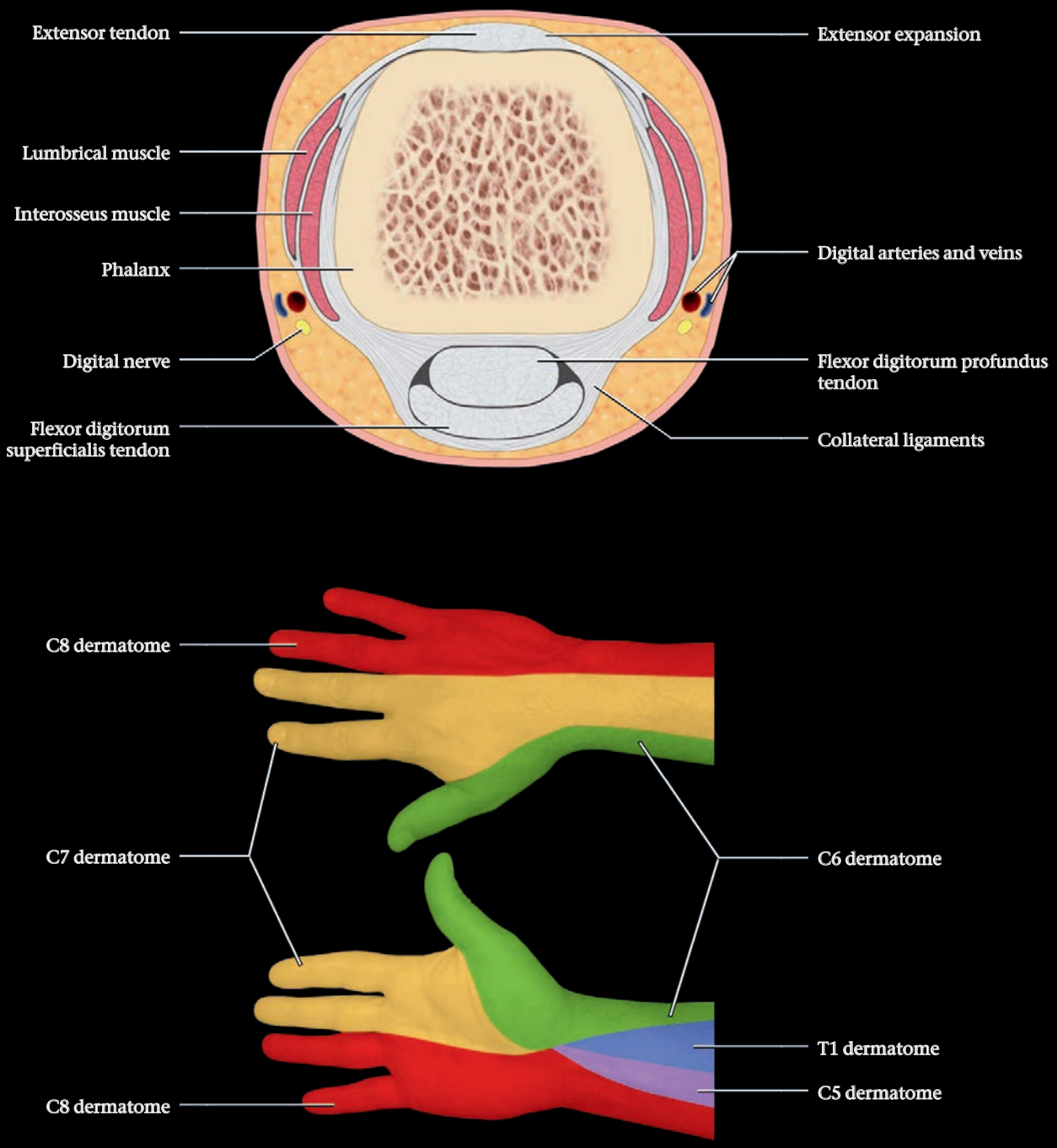
FINGERS

TRANSVERSE US, EXTENSOR ASPECT



(Top) *Transverse grayscale ultrasound shows the metacarpal head/neck region of the extensor aspect of the fingers. The extensor tendons of the hand do not have a complete synovial sheath. They are covered by thin paratenon. The tendons have an ovoid configuration.* ***(Middle)*** *Transverse grayscale ultrasound shows the extensor aspect of the fingers at the metacarpal head region. At the proximal phalanx extending over the middle phalanx, the extensor tendons spread out and connect to the extensor expansion or hood.* ***(Bottom)*** *Transverse grayscale ultrasound shows the extensor aspect of the fingers at the proximal phalanx level. With expansion of the extensor tendon, it becomes very thin such that the normal tendon is difficult to illustrate on the dorsum of the fingers. If injured, the tendon swells and is usually more readily seen.*

GRAPHICS, AXIAL FINGER AND HAND DERMATOMES



(Top) *Graphic shows the transverse section of a finger depicting the relationships of the digital nerve, vessels, and tendons to the phalanx. On the dorsal aspect, the extensor expansion interdigitate with the extensor digitorum communis (EDC) tendons to prevent lateral translation. On the palmar side, the collateral ligaments extend from the palmar aponeurosis in the palm to fuse with the fibrous digital sheaths. Other thickenings of the fibrous digital sheaths form annular pulleys and cruciform bands. The common digital artery and the accompanying nerve intervene between the lumbrical muscle and the tendons.* ***(Bottom)*** *Dermatomes of hand and wrist correlated to corresponding cervical or thoracic nerves. It is necessary for a physician to test the integrity of spinal cord segment C5 to T1 in the upper limb. Usually, physicians will test the C6 to C8 dermatomes in the hand, i.e., the thumb represents C6 dermatome, the middle finger tip represents C7 dermatome, and the little finger represents C8 dermatome.*

RADIAL NERVE

TERMINOLOGY

Abbreviations
- Extensor digitorum (ED)
- Extensor carpi radialis brevis (ECRB)
- Extensor digiti minimi (EDM)
- Extensor carpi ulnaris (ECU)
- Extensor pollicis longus (EPL)
- Abductor pollicis longus (APL)
- Extensor indicis (EI)

GROSS ANATOMY

Arm
- Radial nerve is largest branch of posterior cord of brachial plexus
  - Receives contributions from cervical roots C5-C8
  - Contains motor and sensory components that supply muscles of extensor compartments of arm, forearm, and hand
- Lies between coracobrachialis and teres major muscles and then between bellies of medial and lateral head of triceps
- Runs deep to triceps in spiral groove and then deep to brachioradialis
- ~ 10 cm proximal to lateral epicondyle of humerus, radial nerve penetrates lateral intermuscular septum to enter anterior space of upper arm
- Just anterior to lateral epicondyle, nerve bifurcates into sensory (superficial branch of radial nerve) and motor (deep branch of radial nerve and posterior interosseous nerve) components

Forearm
- Branches of radial nerve
  - Divides at level of lateral epicondyle
  - Superficial
    - Purely sensory
    - Direct continuation of radial nerve
    - Courses distally, deep to brachioradialis, to the posterior compartment distal forearm and then to the dorsal wrist
    - Divides into lateral branch (supplies radial wrist and thumb skin) and medial branch (supplies mid and ulnar wrist skin)
    - Dorsal digital nerves supply ulnar thumb, index, middle, and radial ring fingers
  - Deep
    - Purely motor
    - Enters supinator, then exits distally and runs posteriorly as posterior interosseous nerve
    - Supplies ECRB, supinator, ED, EDM, ECU, EPL, APL, and EL

Hand: Branches of Radial Nerve
- Not usually seen on routine imaging
- No motor innervation in hand
- Sensory: Dorsal surface from radiocarpal joint to just distal to proximal interphalangeal joints for digits 1-3 and radial 1/2 of 4th digit
  - Gives terminal branches to supply skin of lateral 2/3 dorsum of wrist & hand and lateral 2.5 digits

ANATOMY IMAGING ISSUES

Imaging Recommendations
- Use high-frequency, at least ≥ 7.5 MHz transducer
- Radial nerve is best identified at lateral aspect of distal arm where it runs deep to brachialis
  - Identified deep to triceps in spiral groove midhumeral level
  - Or in proximal aspect arm medially
    - Lies just deep to brachial artery
- Assess shape, size, echotexture, and integrity of nerve
  - Trace medium-sized branches by following their course as they branch from parent nerve
- Examination of nerves along transverse plane is preferable to longitudinal scanning as it allows easier, continuous following of nerves throughout limb

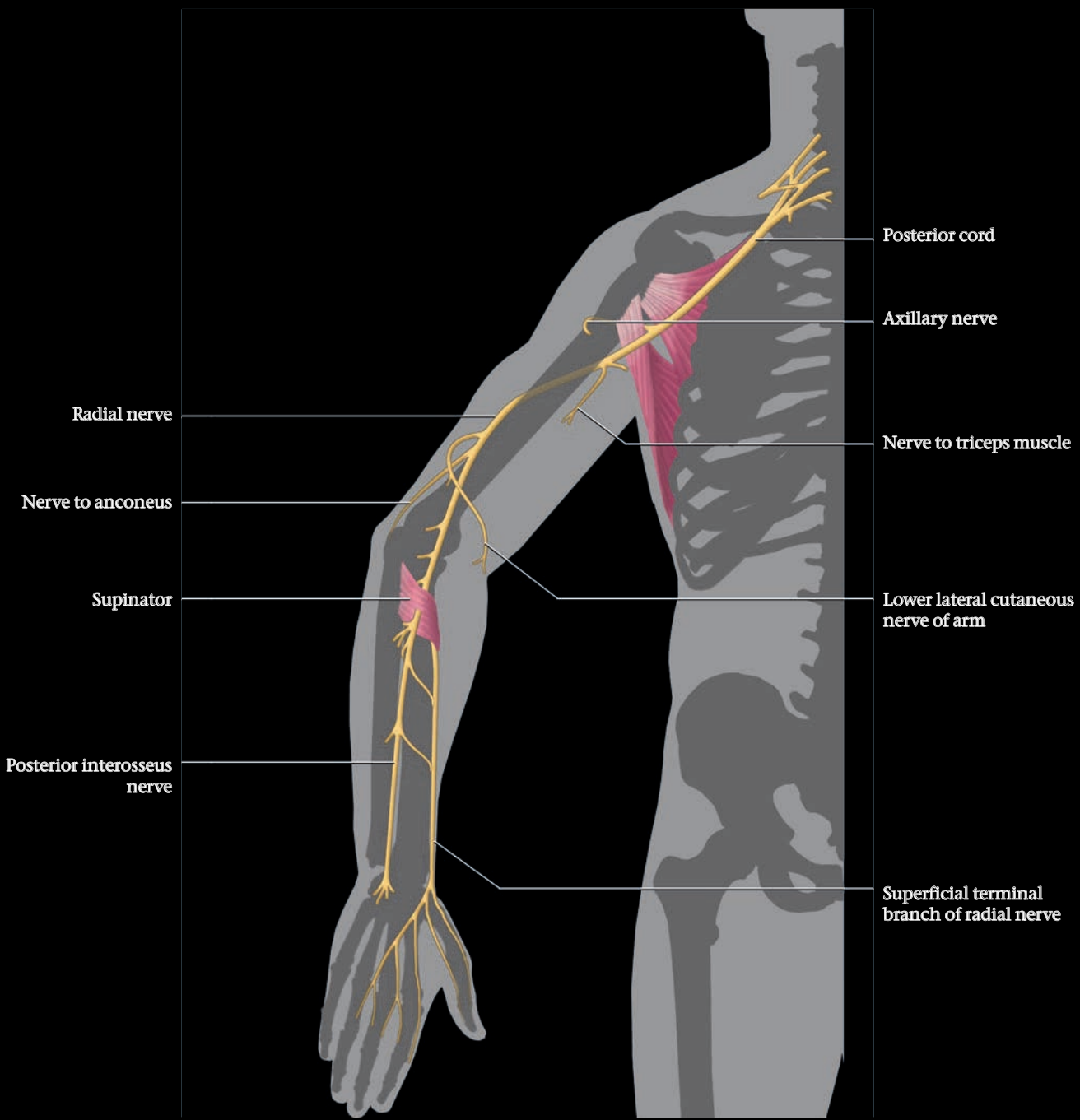
Imaging Approaches
- Ultrasound
  - Nerve echotexture
    - Transverse: Uniformly dispersed hypoechoic dots (nerve fascicles) separated by hyperechoic epineurium
    - Longitudinal: Parallel hypoechoic tracts of uniform caliber
    - Overall gain control and focus settings optimized for adequate visualization of nerve

Imaging Pitfalls
- Smaller nerves and nerve branches (1-2 mm) are difficult to identify, and their location may only be inferred by adjacent vessels
- Anisotropy artifacts may affect scanning, especially in short axis; tilting transducer during scanning helps to achieve best view
- Structural compression is easier to appreciate than functional compression

CLINICAL IMPLICATIONS

Clinical Importance
- Sites of potential nerve entrapment of radial nerve
  - Lateral to long head of triceps due to fibrous arch
  - Spiral groove between medial and lateral heads of triceps muscle due to fibrous arch, fractures, tourniquet
  - Between brachialis and brachioradialis muscles at antecubital fossa due to muscle (body builders)
  - Posterior interosseous nerve by arcade of Frohse (superficial proximal margin of supinator) or recurrent radial artery (leash of Henry) crossing just proximal to arcade
  - Posterior interosseous nerve between deep and superficial heads of supinator muscle (supinator syndrome)
  - Superficial radial nerve between brachioradialis and extensor carpi radialis longus (ECRL) in mid to distal forearm (Wartenberg syndrome)

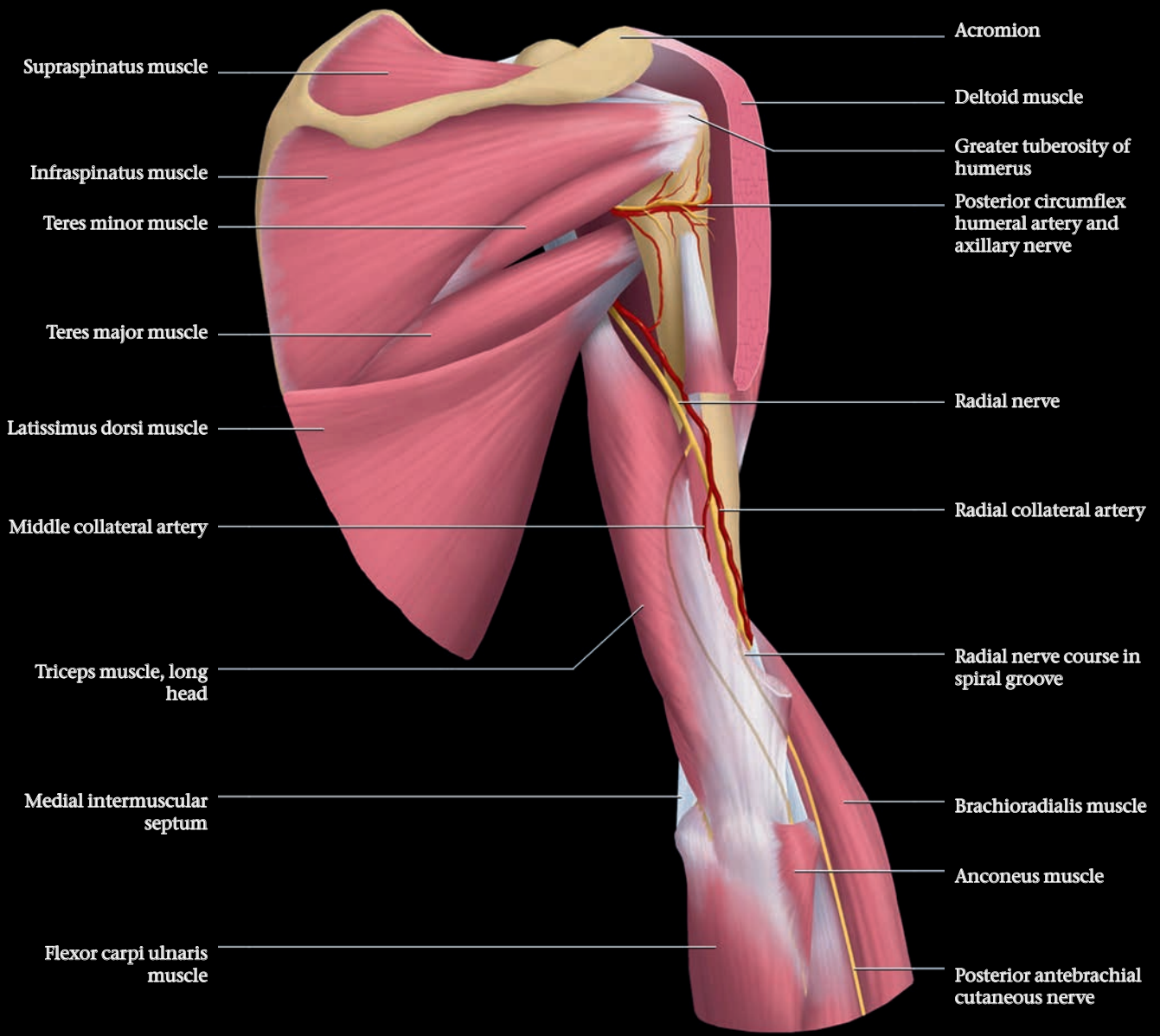
GRAPHIC, RADIAL NERVE



Graphic shows the course and distribution of the radial nerve. The radial nerve arises from the posterior cord of the brachial plexus (C5-C8, T1). It spirals posterolaterally around the humerus with the deep brachial artery located anterolateral between the brachialis and the brachioradialis. It gives off the posterior cutaneous nerve of the forearm, which passes posterior to the lateral condyle and supplies the posterior forearm. It divides into deep and superficial branches at the lateral epicondyle. The deep branch is purely motor and pierces the supinator muscle and winds around the lateral aspect of the radial neck. The superficial branch is purely sensory and is located in the anterolateral aspect of the forearm, superficial to the supinator and pronator teres muscles.

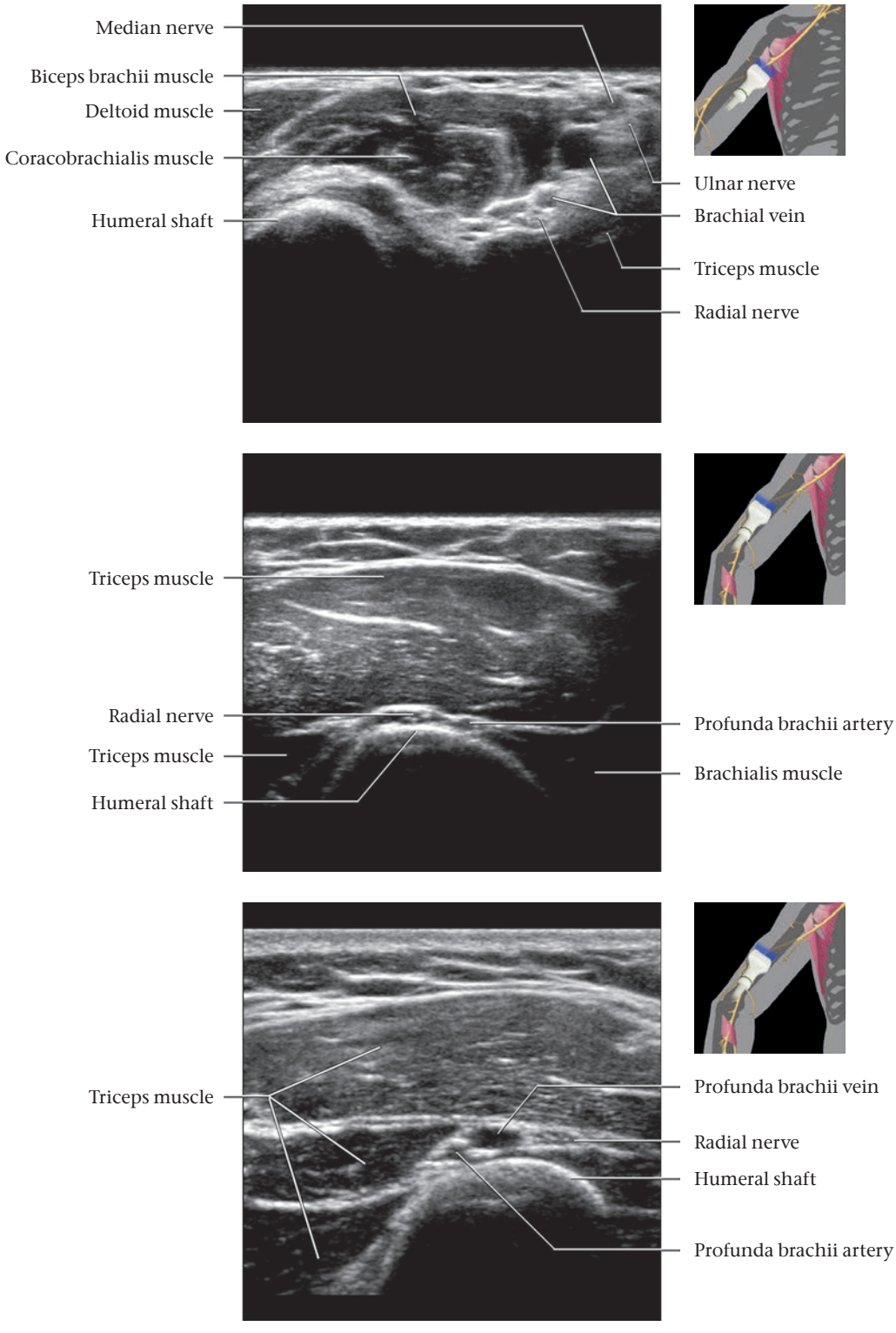
RADIAL NERVE

GRAPHIC, POSTERIOR ARM



Graphic shows the course of the radial nerve in the posterior aspect of the arm. The radial nerve spirals posterolaterally around the humerus with the deep brachial artery. It gives off the posterior cutaneous nerve of the forearm, which passes posterior to the lateral condyle and supplies the posterior forearm. It is located anterolaterally, between the brachialis and brachioradialis, where it supplies the triceps, anconeus, brachioradialis, and the lateral portion of the brachialis.

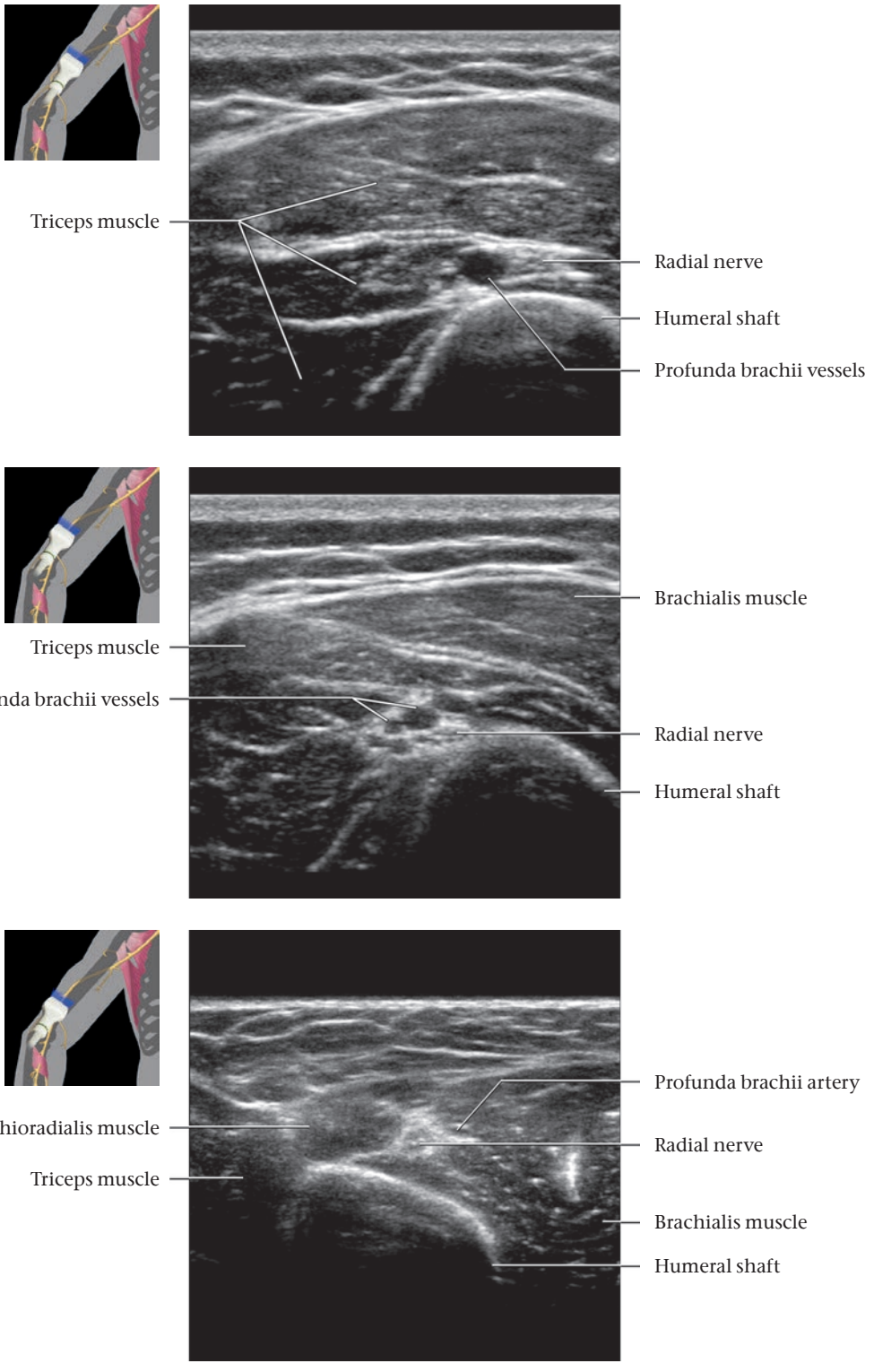
TRANSVERSE US, ARM



(Top) *Transverse grayscale ultrasound section shows the radial nerve in the proximal 1/3 of the arm. The radial nerve is a continuation of the posterior cord of the brachial plexus. It supplies the triceps and the supinator. In the proximal arm, it lies deep to the brachial artery and vein.* ***(Middle)*** *Transverse grayscale ultrasound shows the radial nerve at the mid 1/3 of the arm. The radial nerve may be injured as it passes around the posterior aspect of the mid to distal 1/3 of the humeral shaft. This injury may occur at the time of fracture, during fracture manipulation or fixation, or as a result of postoperative fibrosis.* ***(Bottom)*** *Transverse grayscale ultrasound shows the radial nerve at the mid 1/3 of the arm (coned view). The radial nerve is accompanied in the spiral groove by the profunda brachii artery and vein.*

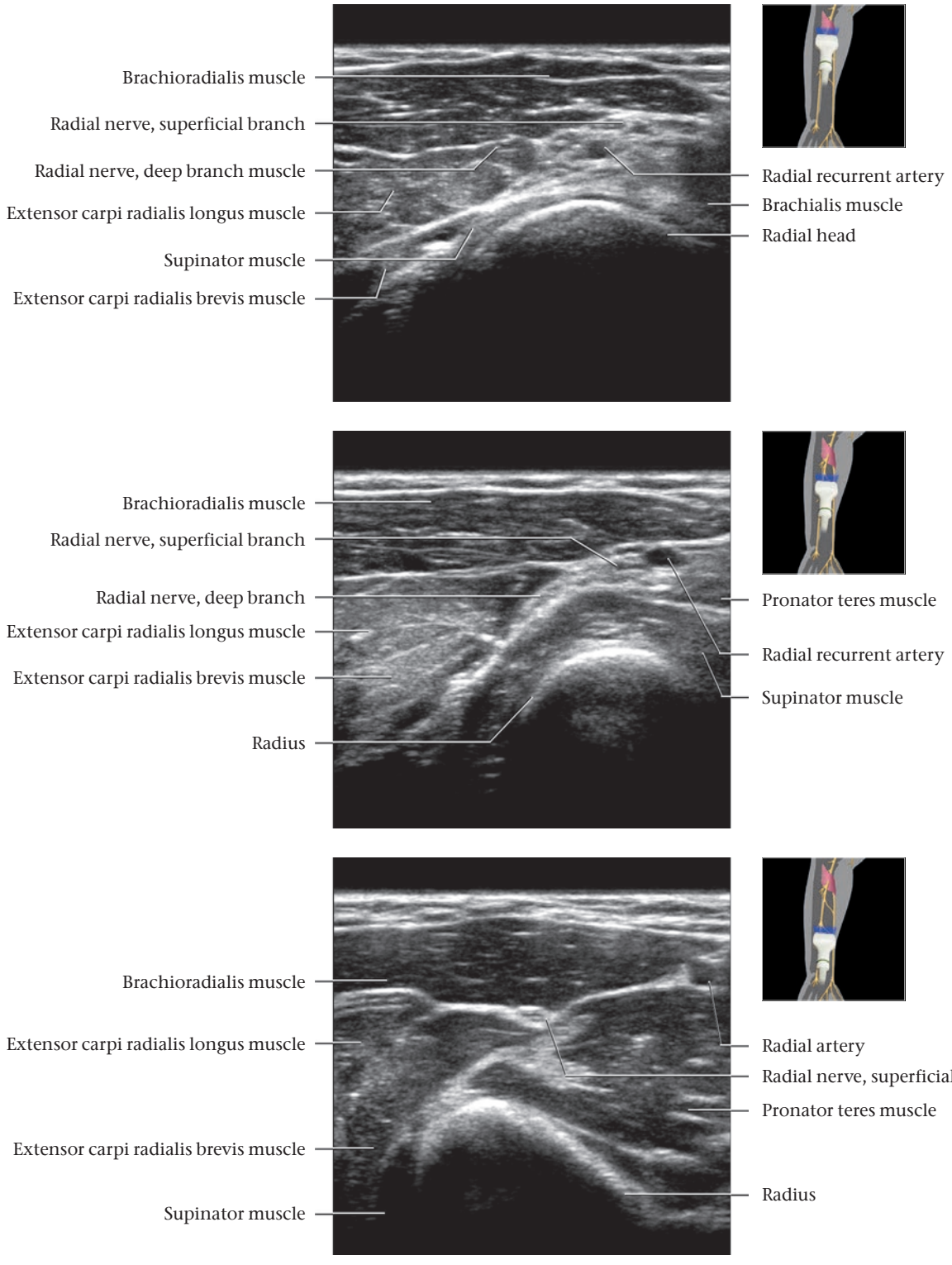
RADIAL NERVE

TRANSVERSE US, SPIRAL GROOVE



(Top) *Transverse grayscale ultrasound shows the radial nerve in the midpart of the spiral groove (coned view). The surgeon must be aware of the site of the radial nerve when performing fixation of the humerus, as the fixator screws or plate may potentially damage the radial nerve.* ***(Middle)*** *Transverse grayscale ultrasound shows the radial nerve in the distal aspect of the spiral groove in the midhumerus region.* ***(Bottom)*** *Transverse grayscale ultrasound shows the radial nerve on the volar aspect of the distal 1/3 of the arm. The radial nerve passes from the posterior to the anterior compartment by piercing the lateral intermuscular septum. Compression of the radial nerve at the lateral intermuscular septum may occur. The radial nerve may be compressed between the brachioradialis and brachialis muscles in very muscular individuals.*

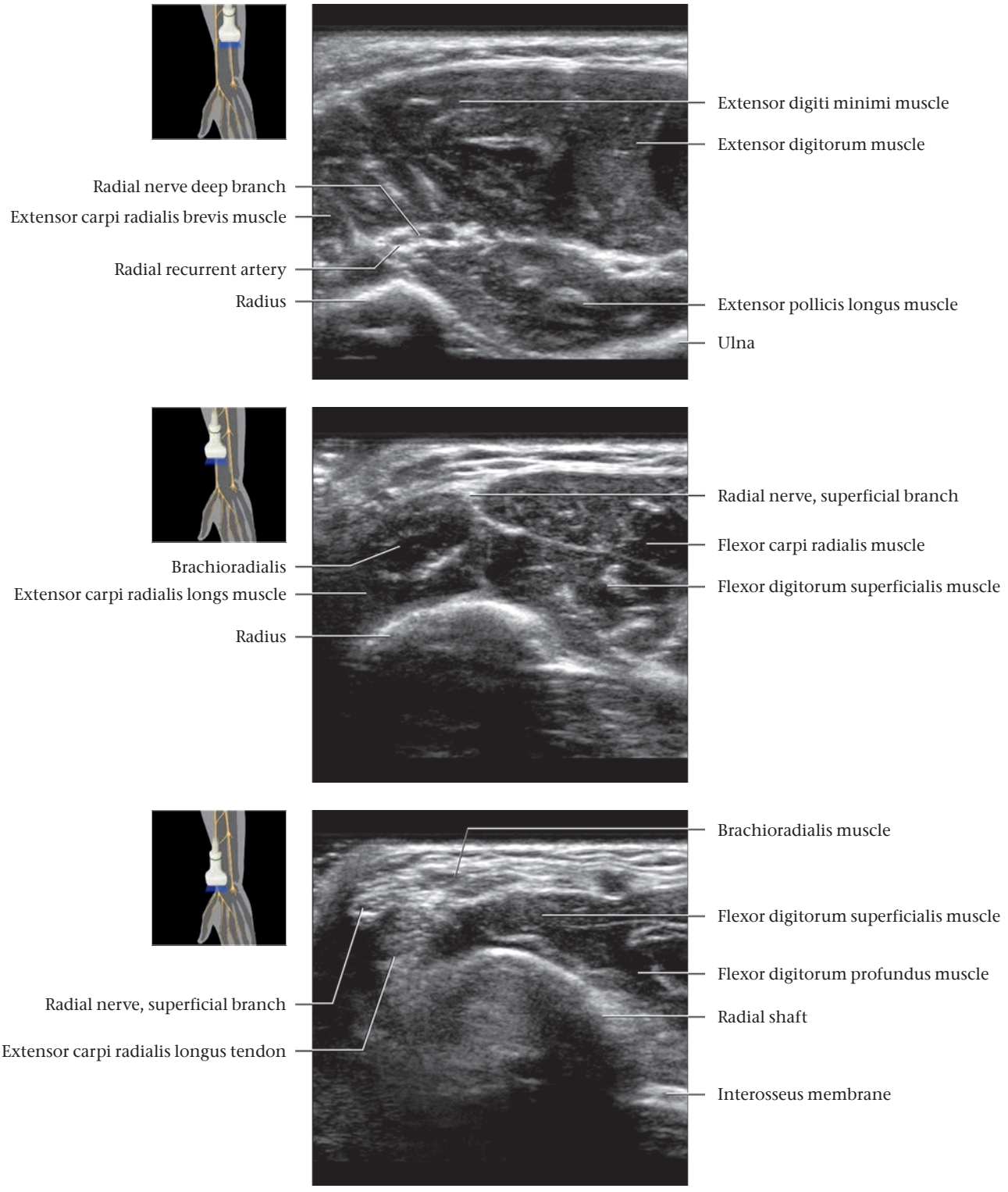
TRANSVERSE US, POSTERIOR FOREARM



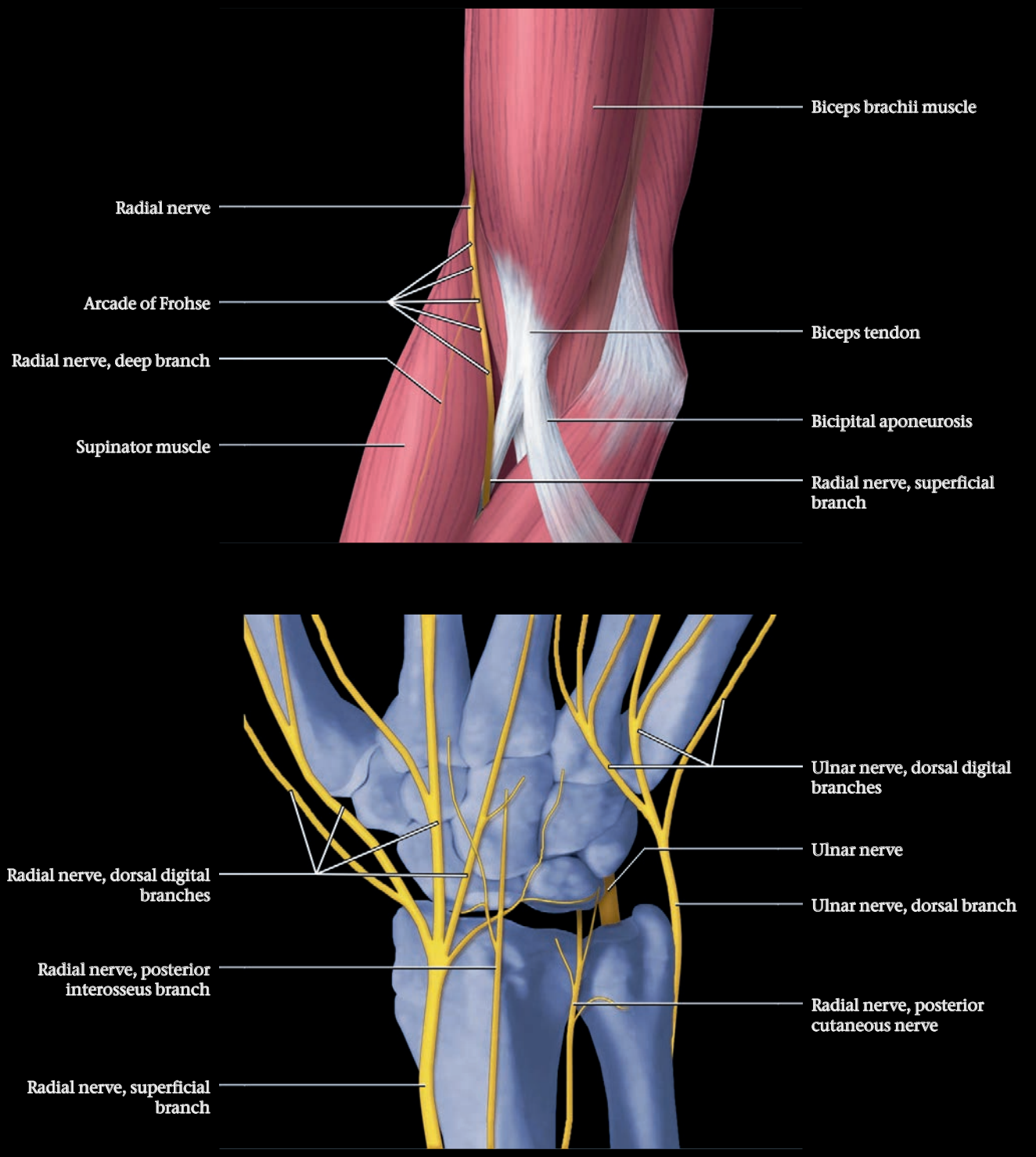
(Top) *Transverse grayscale ultrasound shows the radial nerve course in the proximal forearm. The radial nerve passes in front of the lateral epicondyle. It can be readily identified deep to the brachioradialis muscle. It divides into superficial and deep branches in the region of the radial head. The radial nerve is prone to compression between the radial head and the supinator muscle (radial tunnel syndrome).* ***(Middle)*** *Transverse grayscale ultrasound shows the radial nerve at the proximal forearm. The superficial branch of the radial nerve continues to descend in the forearm deep to the brachioradialis muscle. The deep branch pierces the supinator muscle, after which it is known as the posterior interosseus nerve.* ***(Bottom)*** *Transverse grayscale ultrasound shows the radial nerve in the midforearm. The deep branch of the radial nerve may be compressed as it passes through the supinator muscle (arcade of Frohse).*

RADIAL NERVE

TRANSVERSE US, FOREARM



(Top) *Transverse grayscale ultrasound shows the deep branch of the radial nerve on the volar aspect of the distal forearm.* ***(Middle)*** *Transverse grayscale ultrasound shows the superficial branch of the radial nerve on the volar aspect of the distal forearm. About 8 cm proximal to the radial styloid, the superficial branch of the radial nerve emerges from underneath the brachioradialis muscle to lie between the brachioradialis and the extensor carpi radialis longus tendons. It may be compressed in this location (Wartenberg syndrome).* ***(Bottom)*** *Transverse grayscale ultrasound shows the superficial branch of the radial nerve on the radial side of distal forearm close to the wrist. It now lies close to the skin.*



(Top) *Graphic shows the radial nerve course at the anterolateral aspect of the elbow. The deep branch of the radial nerve is potentially prone to impingement at the superficial proximal margin of the supinator muscle (arcade of Frohse) resulting in posterior interosseus nerve syndrome.* ***(Bottom)*** *Graphic shows the nerves of the dorsal wrist. The radial nerve branches in the forearm with the superficial, posterior cutaneous, and posterior interosseus branches supplying the wrist and hand. The ulnar nerve provides branches to both the dorsal and volar wrist.*

MEDIAN NERVE

TERMINOLOGY

Abbreviations
- Flexor digitorum profundus (FDP)
- Flexor digitorum superficialis (FDS)
- Flexor carpi ulnaris (FCU)
- Flexor pollicis longus (FPL)
- Pronator quadratus (PQ)
- Palmaris longus (PL)

GROSS ANATOMY

Arm: Median Nerve
- Arises from both medial and lateral cords of brachial plexus (C6-8, T1)
- Lies medial to brachial artery and vein
- Located deep to biceps aponeurosis in cubital fossa
- Gives articular branches to elbow joint
- Supplies pronator teres, pronator quadratus, and flexors of anterior compartment forearm (except FCU and medial 1/2 of FDP, which are supplied by ulnar nerve)

Forearm: Median Nerve and Branches
- Enters forearm by passing between heads of pronator teres; located in forearm between FDP and FDS
  - Courses distally and attached to deep surface of FDS by a fascial sheath
  - Anterior interosseus nerve
    - Arises from median nerve at level of pronator teres
    - Located in forearm anterior to interosseus membrane, between FPL and FDP
- At wrist, median nerve emerges from lateral side of FDS and becomes more superficial and runs deep to PL tendon toward carpal tunnel
  - Supplies FPL, PQ, and lateral 1/2 of FDP

Wrist and Hand: Median Nerve and Branches
- Median nerve lies along axis of ring finger, i.e., to ulnar side of midline
- Lies deep to antebrachial fascia and palmaris longus before dipping deeply to enter carpal tunnel
- At distal radioulnar joint: Nerve is rounded, deep to PL, medial and superficial to FCR and FPL, and lateral and superficial to FDS
- Carpal tunnel is a fibroosseous tunnel located immediately distal to volar wrist crease
  - Formed by carpal bones and flexor retinaculum (transverse carpal ligament)
  - Flexor retinaculum attaches to pisiform, hook of hamate, scaphoid, and trapezium
  - 9 structures pass through carpal tunnel
    - 4 FDS tendons, 4 FDP tendons, FPL tendon, and median nerve
    - Median nerve is located superficially in carpal tunnel just deep to retinaculum
  - Tunnel outlet is narrowest part of carpal tunnel
- Branches
  - Motor to thenar and 1st and 2nd lumbrical muscles
  - Sensory to radial 1/2 of palm, radial 3.5 digits
    - Palmar cutaneous branch typically arises proximal to carpal tunnel
  - Median nerve divides just distal to carpal tunnel

ANATOMY IMAGING ISSUES

Imaging Recommendations
- Examination of nerve in transverse plane is preferable to longitudinal scanning since it allows nerve to be followed continuously throughout limb
- Use proximal and distal borders of retinaculum as markers of carpal tunnel

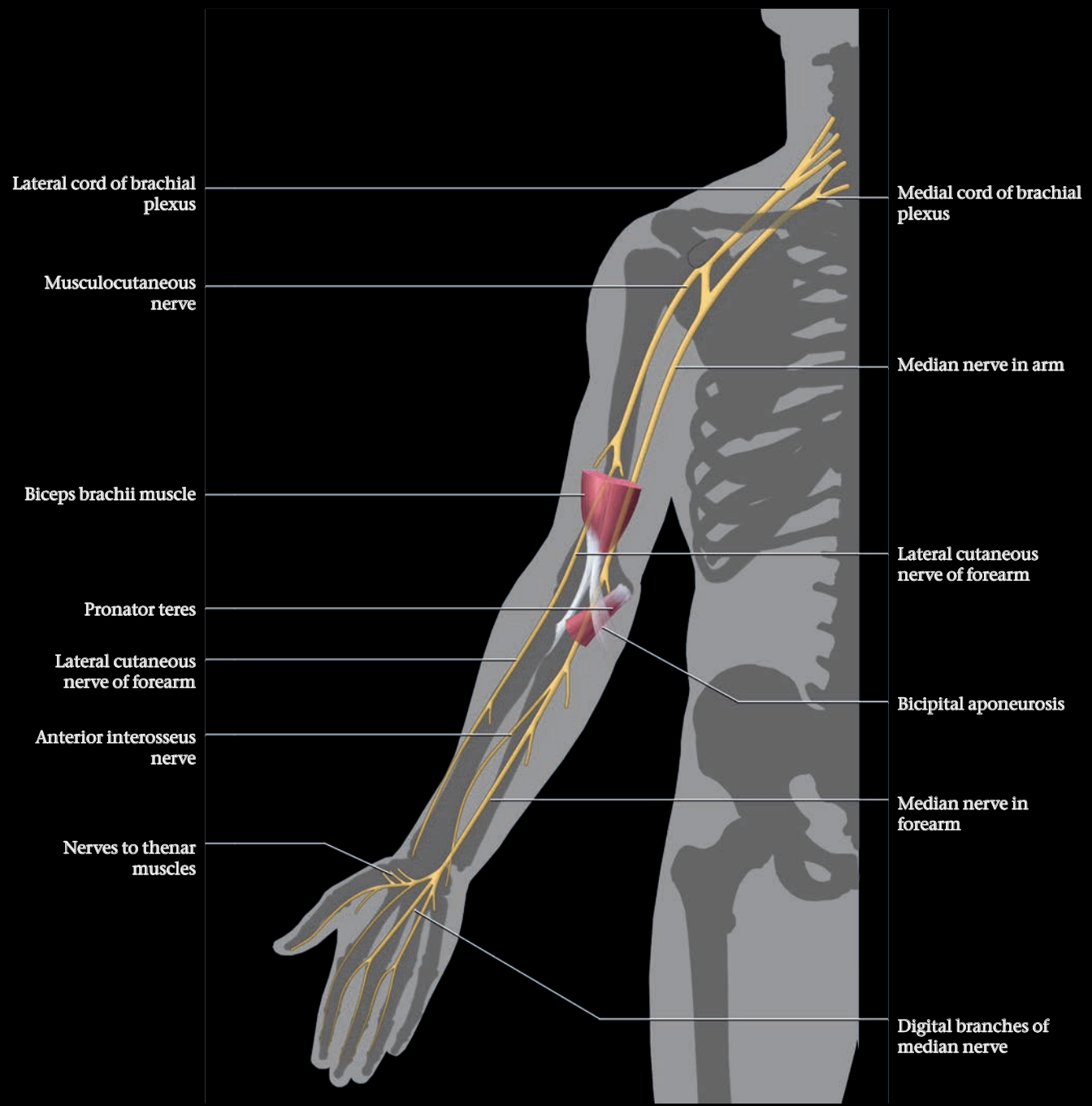
Imaging Approaches
- Ultrasound
  - Use high-frequency 12-17 MHz transducer

Imaging Pitfalls
- Median nerve may be bifid
  - If quantifying size of nerve, both components should be measured and summated
- Angle transducer at right angles to nerve as angulation will ↑ nerve caliber
  - May need to make use of anisotropy to best differentiate nerve from tendons in carpal tunnel
- Avoid too much transducer pressure as this will ↓ nerve caliber and ↑ flattening
- Median nerve may be difficult to see at tunnel outlet in subjects with thick palmar skin

CLINICAL IMPLICATIONS

Clinical Importance
- Normal cross-sectional area of median nerve ranges from 3.9-9.0 mm²
  - Mean fascicular diameter ranges from 0.3-0.5 mm
  - Nerve thickening is considered if size changes beyond above mentioned limits (e.g., > 10 mm² cross-sectional area).
  - The larger the median nerve, the greater the likelihood of carpal tunnel syndrome
- Potential sites of median nerve compression
  - Deep to ligament of Struthers
    - Ligament between medial epicondyle and anomalous bony spur arising from distal humeral diaphysis (present in 1% population)
    - May compress median nerve or brachial artery or both
  - Between brachialis and bicipital aponeurosis
    - Bicipital aponeurosis = medial fascial expansion of biceps tendon that extends superficial to brachial artery and median nerve and merges with investing fascia forearm
  - Between heads of pronator teres
    - Either median nerve or anterior interosseus nerve may be compressed
  - Carpal tunnel syndrome
    - Pain, paresthesia, numbness due to compression of nerve in carpal tunnel
    - Most common compressive neuropathy
    - Nerve swollen proximal to inlet ± at inlet ± at outlet ± distal to outlet
    - Do not use opposite side as comparative standard as subclinical compression common

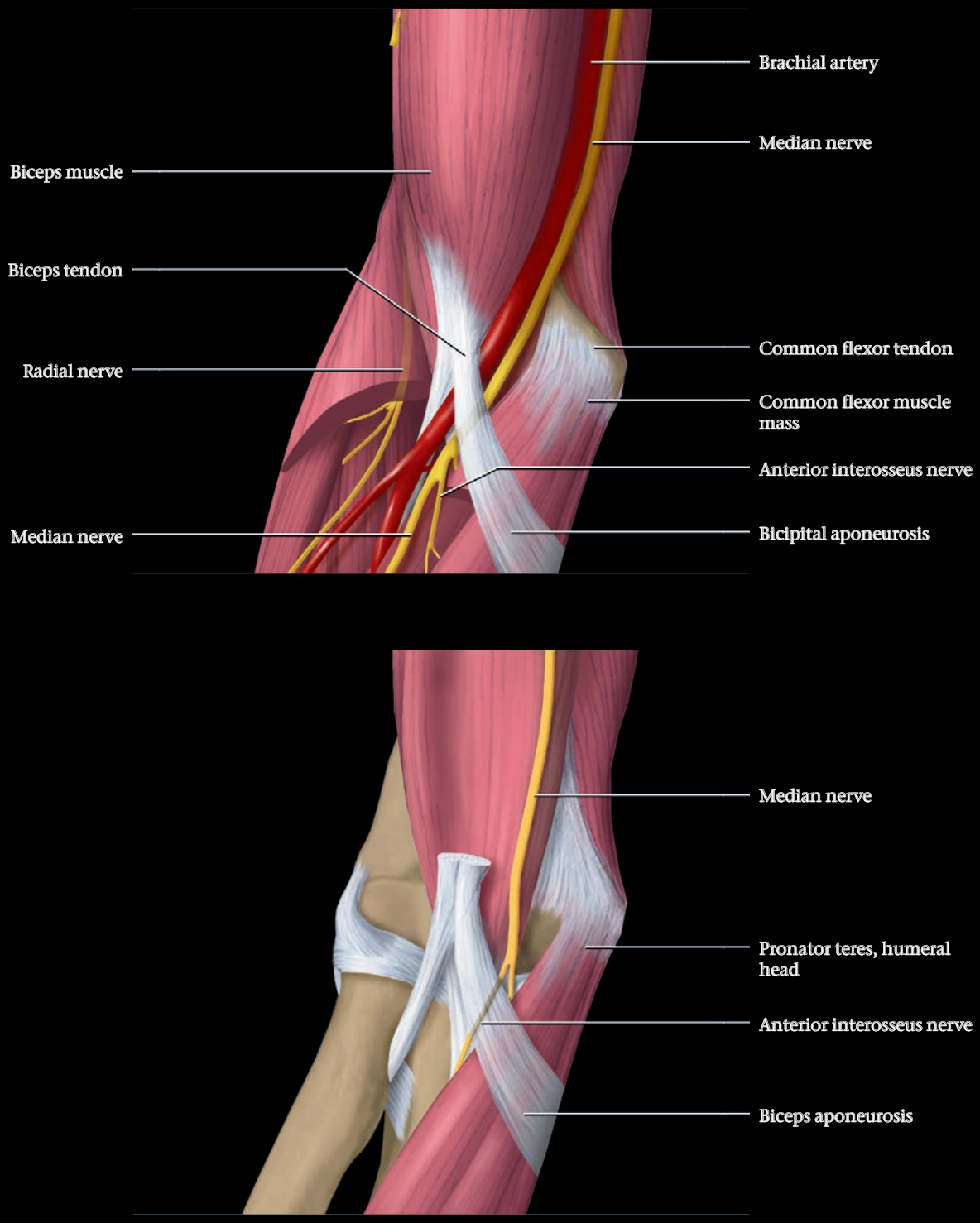
GRAPHIC, MEDIAN NERVE



Graphic shows the course and distribution of the median and musculocutaneous nerves. The median nerve arises from the medial and lateral cords of the brachial plexus (C6-8, T1). It travels together with other nerves of the arm. In the elbow, it is located deep to the biceps aponeurosis, enters the forearm by passing between the heads of the pronator teres, and is located in the forearm between the flexor digitorum superficialis and profundus muscles. The musculocutaneous nerve arises from the lateral cord of brachial plexus (C5, 6, 7). It lies between the brachialis and biceps brachii muscles and supplies both of them. It then becomes superficial at the elbow and continues laterally as the lateral cutaneous nerve of the forearm, which innervates the skin of the lateral side of the forearm.

MEDIAN NERVE

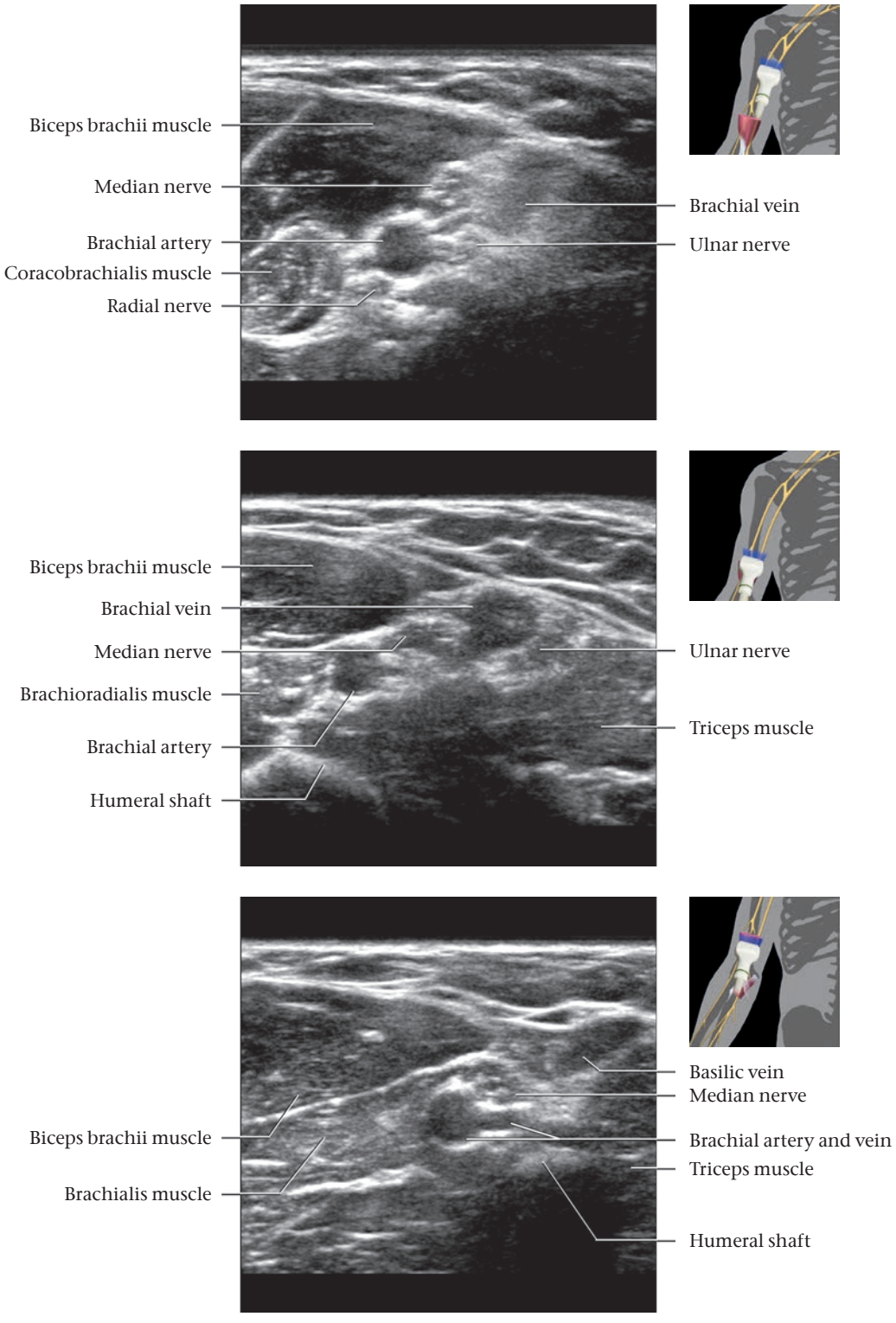
GRAPHIC, CUBITAL FOSSA



*(**Top**) Graphic of the anterior view of the cubital fossa shows the median nerve and brachial artery passing underneath the biceps aponeurosis. The anterior interosseus nerve arises from the median nerve as the median nerve passes between 2 heads of the pronator teres muscle. (**Bottom**) The median nerve may be entrapped between 2 heads of the pronator teres muscle or by the overlying biceps aponeurosis. The median nerve gives rise to the articular branches to the elbow joint. It supplies the pronator teres, pronator quadratus, and flexors of the anterior compartment of the forearm (except the flexor carpi ulnaris and medial 1/2 of the flexor digitorum profundus, which are supplied by the ulnar nerve).*

MEDIAN NERVE

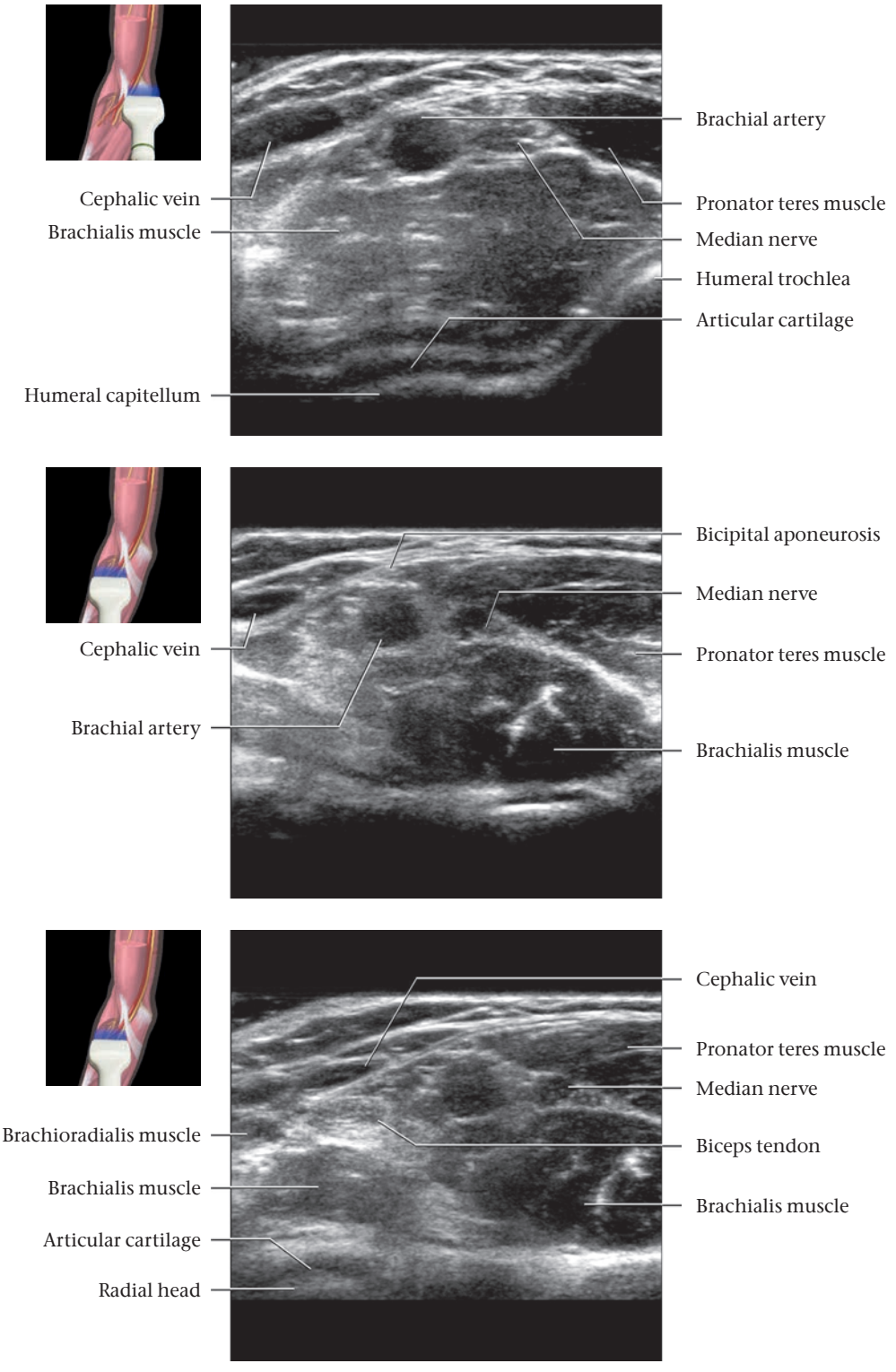
TRANSVERSE US



(Top) *Transverse grayscale ultrasound shows the median nerve at the proximal arm. The median nerve arises from the lateral and medial cords of the brachial plexus. In the proximal arm, it lies just lateral to the brachial vein and artery.* ***(Middle)*** *Transverse grayscale ultrasound section shows the median nerve at the midarm. Little happens to the median nerve in the upper to midarm. It gives off no branches and is not prone to compression by normal structures.* ***(Bottom)*** *Transverse grayscale ultrasound shows the median nerve of the distal arm. The median nerve passes over the brachial artery and vein from lateral to medial. There is occasionally a ligament (of Struthers) in the distal arm with a bony spur attached to the humerus ~ 5 cm proximal to the medial epicondyle. The pronator teres gains additional attachment from this ligament. The median nerve may be compressed deep to this ligament.*

MEDIAN NERVE

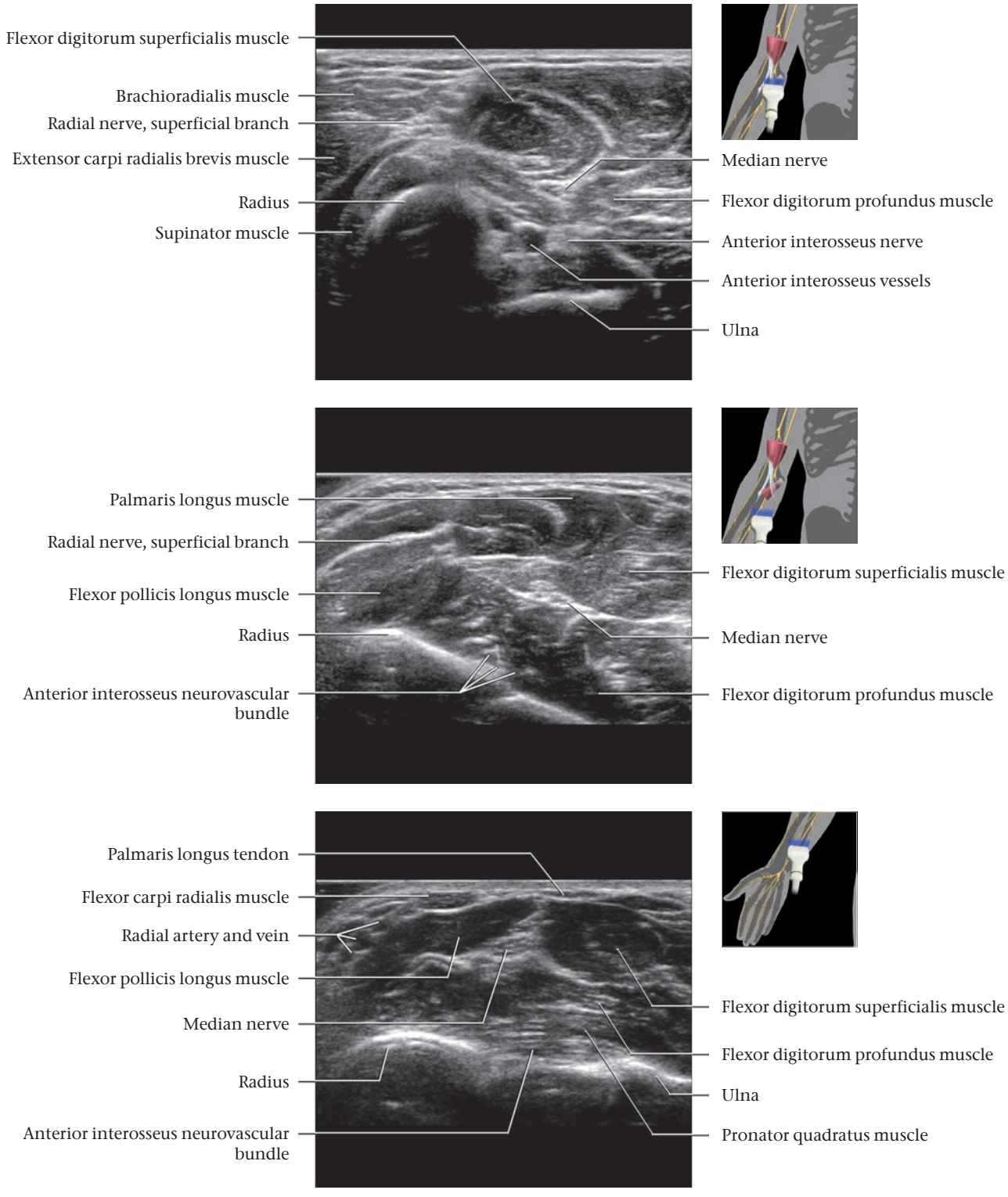
TRANSVERSE US



(Top) *Transverse grayscale US shows the median nerve at the distal arm. The median nerve travels deep to the bicipital aponeurosis. A fascial aponeurosis (a.k.a. lacertus fibrosis) arises from the biceps musculotendinous junction and inserts into the antebrachial fascia. The median nerve may be compressed deep to this fascia.* ***(Middle)*** *Transverse grayscale US shows the median nerve at the elbow region.* ***(Bottom)*** *Transverse grayscale US shows the median nerve at the proximal forearm. The median nerve is also prone to compression between the 2 heads of the pronator teres muscle (i.e., common flexor origin head and coronoid process head). The median nerve branches as it passes through these heads (giving rise to the anterior interosseus nerve) and may be compressed at this location (pronator teres syndrome). Pain in forearm or hand occurs with either prolonged forearm pronation or recurrent pronation and supination of forearm.*

MEDIAN NERVE

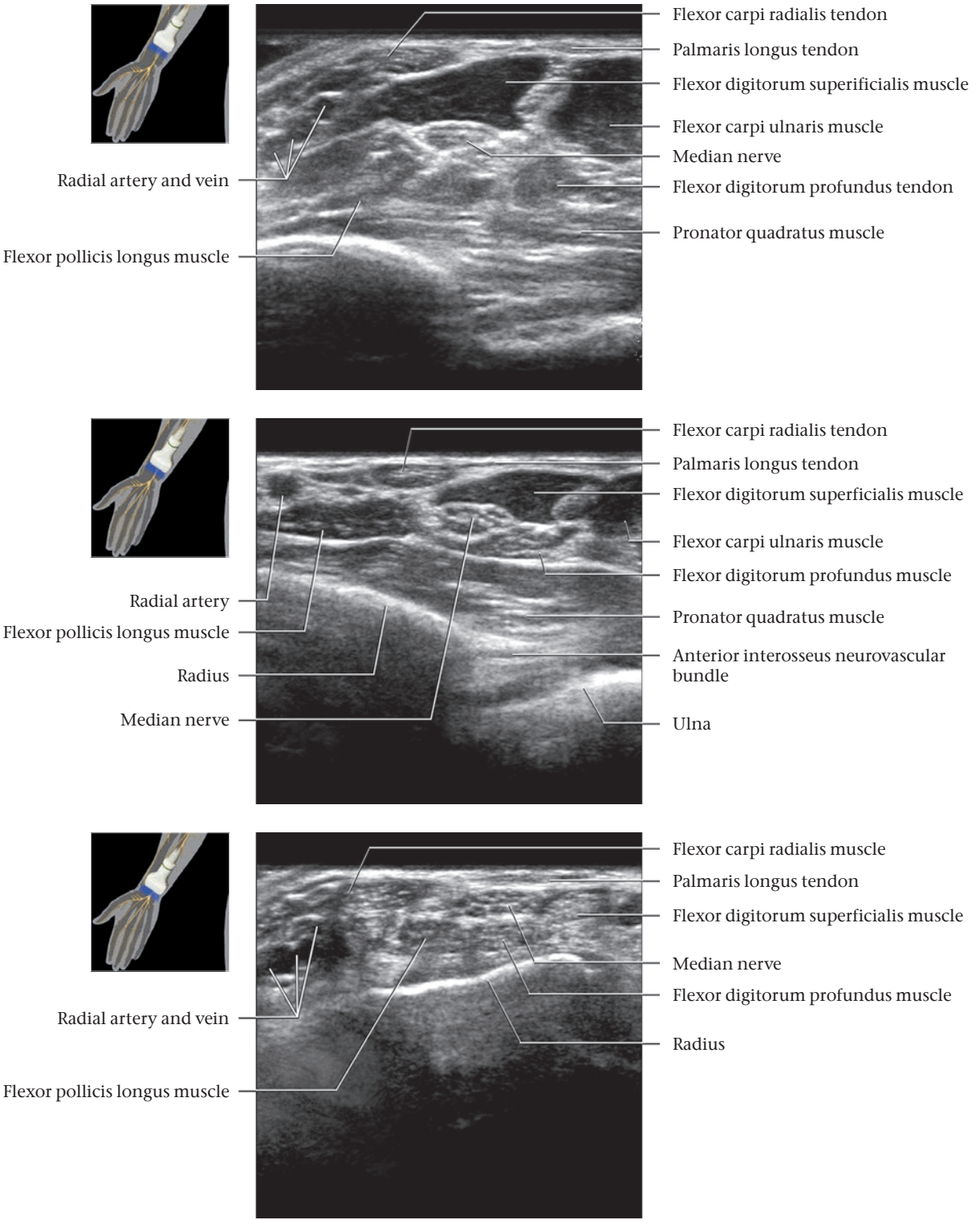
TRANSVERSE US



(Top) *Transverse grayscale ultrasound shows the median nerve at the proximal forearm. The anterior interosseus nerve supplies all the muscles of the anterior compartment of the forearm except the ulnar 1/2 of the flexor digitorum profundus muscle. It may be injured with fracture of the radial shaft.* ***(Middle)*** *Transverse grayscale ultrasound shows the median nerve at the midforearm. The median nerve is clearly identified in the mid-distal forearm as it travels between the flexor digitorum superficialis and profundus muscles.* ***(Bottom)*** *Transverse grayscale ultrasound shows the median nerve at the distal forearm.*

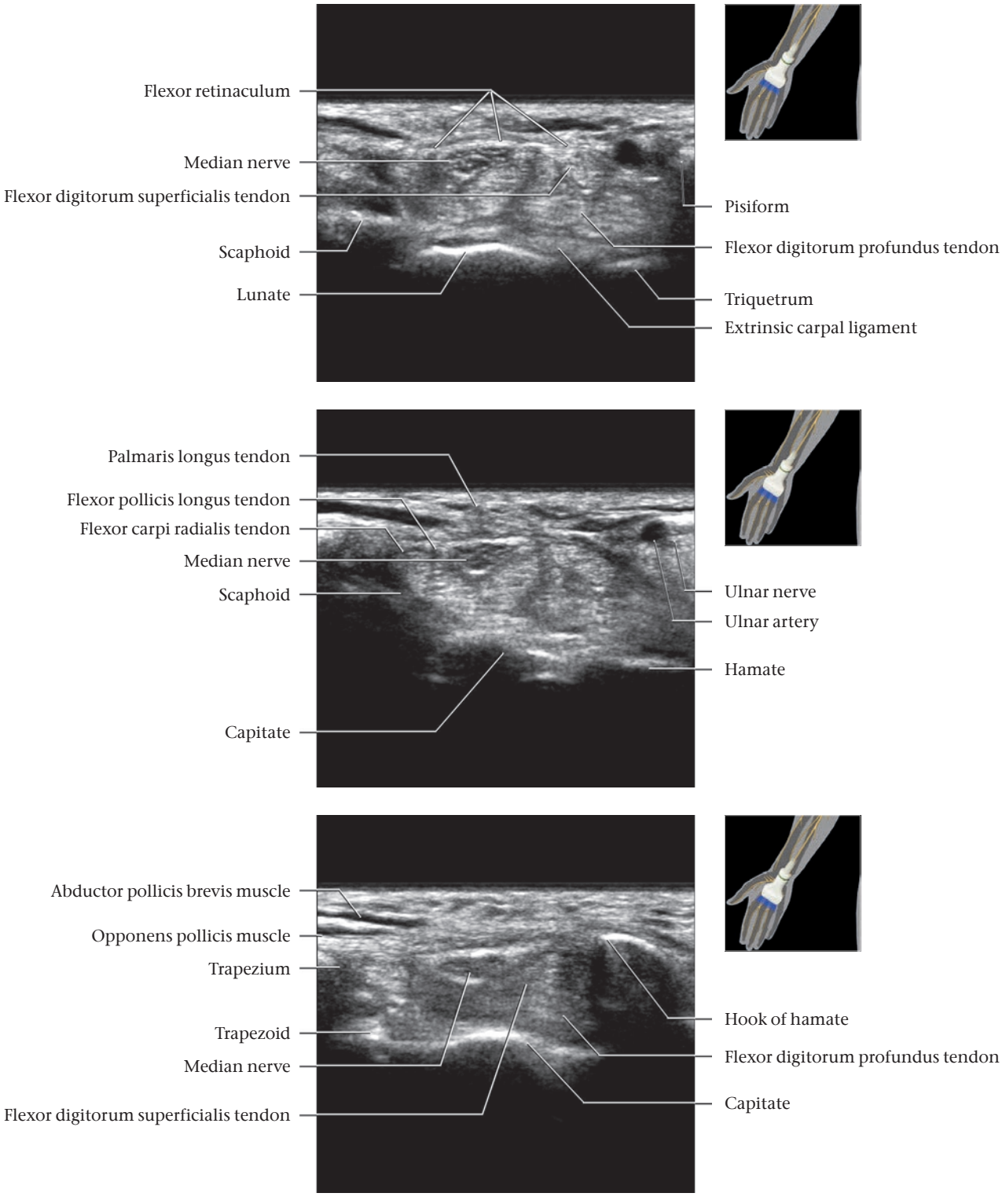
MEDIAN NERVE

TRANSVERSE US, WRIST



(Top) *Transverse grayscale ultrasound shows the median nerve in the distal forearm.* ***(Middle)*** *Transverse grayscale ultrasound shows the median nerve just proximal to the wrist. The median nerve gives off the palmar cutaneous branch in the distal forearm. This branch innervates the skin on the palm of the hand.* ***(Bottom)*** *Transverse grayscale ultrasound shows the median nerve just proximal to the carpal tunnel. Just proximal to the carpal tunnel, the median nerve ascends from a deeper position (between the flexor digitorum profundus and superficialis) to lie just deep to palmaris longus tendon. Enlargement of the median nerve in patients with carpal tunnel syndrome may present clinically as a mass-like lesion in this area. In suspected carpal tunnel syndrome, the caliber of the nerve should be measured at this location.*

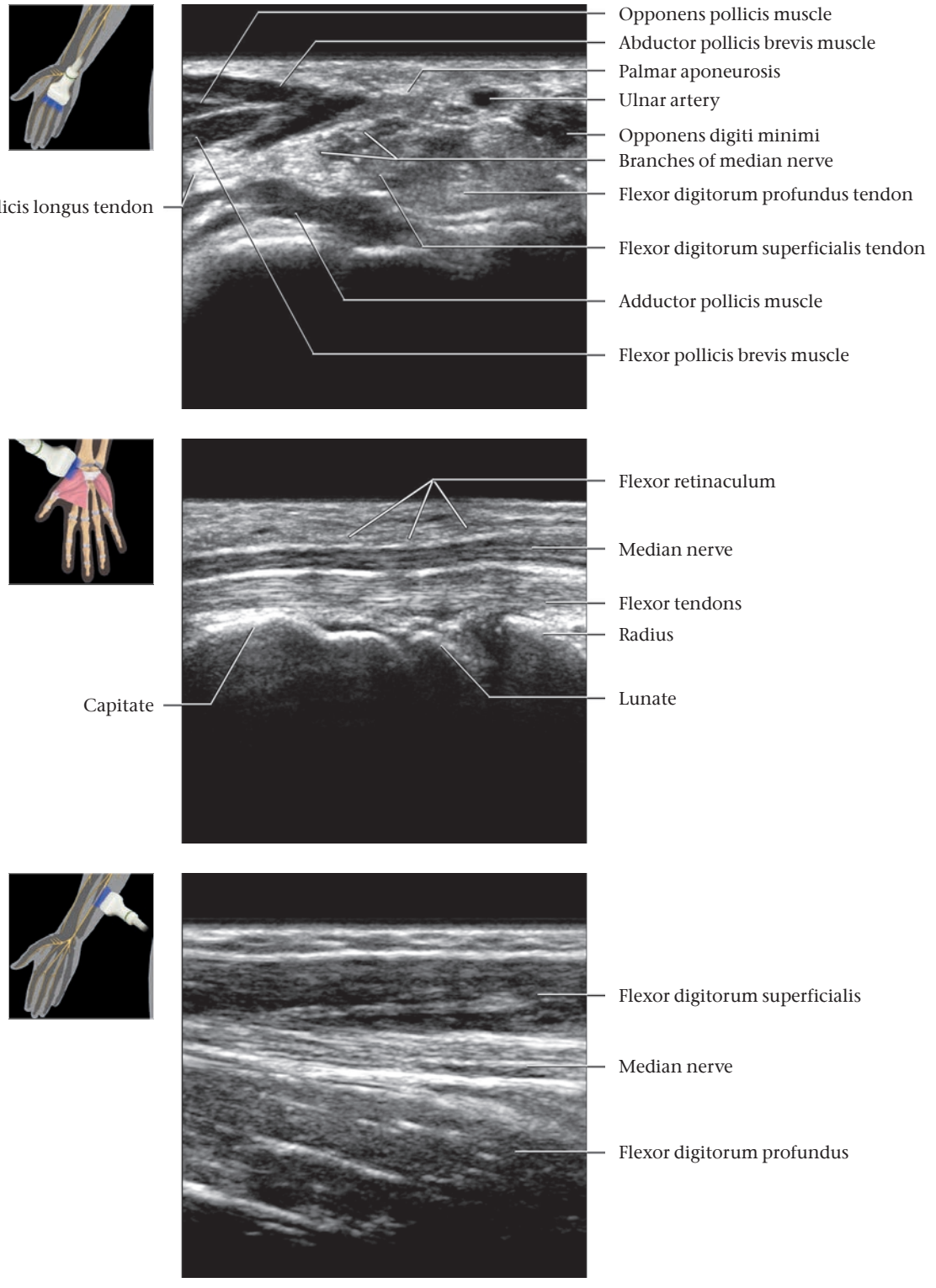
TRANSVERSE US, CARPAL TUNNEL



(Top) *Transverse grayscale ultrasound shows the median nerve at the carpal tunnel inlet. The best way to identify the carpal tunnel is to identify the leading and trailing edges of the flexor retinaculum. The median nerve dips deep to the retinaculum. The cross-sectional area should be measured at this location in suspected carpal tunnel syndrome.* ***(Middle)*** *Transverse grayscale ultrasound shows the median nerve at the midcarpal tunnel. The median nerve lies just deep to the retinaculum. It is variable in shape and changes with flexor tendon movement.* ***(Bottom)*** *Transverse grayscale ultrasound shows the median nerve at the carpal tunnel outlet. The cross-sectional area of the median nerve should also be measured at this location in patients with suspected carpal tunnel syndrome. This is the narrowest part of the carpal tunnel.*

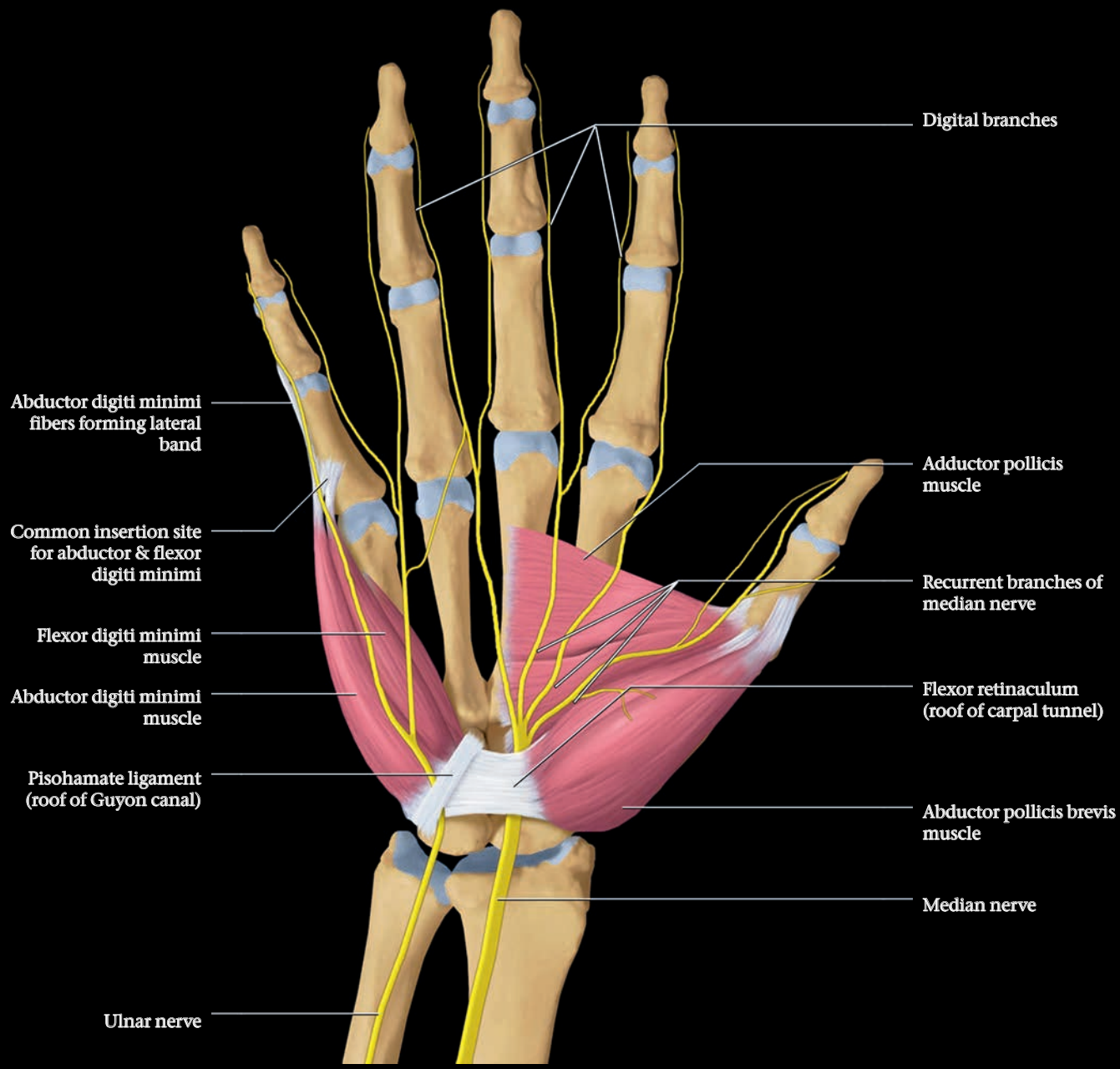
MEDIAN NERVE

TRANSVERSE AND LONGITUDINAL US



(Top) *Transverse grayscale ultrasound shows the median nerve just beyond the carpal tunnel outlet. The median nerve fairly consistently divides into its digital branches just beyond the tunnel outlet. This makes it difficult to get consistent results for nerve caliber at this location.* ***(Middle)*** *Longitudinal grayscale ultrasound shows the median nerve in the carpal tunnel.* ***(Bottom)*** *Longitudinal grayscale ultrasound shows the median nerve in the distal forearm.*

GRAPHIC, PALMAR NERVES



The median nerve travels deep to the flexor retinaculum (within the carpal tunnel). The ulnar nerve travels superficial to the flexor retinaculum and deep to the pisohamate ligament (within the Guyon canal). Both are prone to compression syndromes within these fibroosseous tunnels. Motor supply of the median nerve is to the thenar muscles (via the recurrent branch) and the 1st and 2nd lumbricals. The ulnar nerve motor supply is to all intrinsic muscles of the hand not supplied by the median nerve. Muscle atrophy should prompt an evaluation of the supplying nerve.

ULNAR NERVE

GROSS ANATOMY

Arm: Ulnar Nerve

- Arises from medial cord of brachial plexus (C8, T1)
- Located posteromedially, deep to triceps muscles in distal arm
- Cubital tunnel: Fibroosseous tunnel formed by medial epicondyle, olecranon, & cubital retinaculum (Osborne fascia)
  - Cubital tunnel syndrome
    - Pain, weakness, & numbness in 4th & 5th fingers due to compression of ulnar nerve in cubital tunnel
- May sublux anterior to medial epicondyle in 15% of normal elbows during flexion
- Anconeus epitrochlearis muscle runs on same course at cubital retinaculum, i.e., lies between cubital retinaculum and ulnar nerve
  - From medial cortex of olecranon to medial epicondyle
  - Present in 11% of normal subjects, bilateral in 25%
  - Can contribute to cubital tunnel syndrome
  - When anconeus epitrochlearis muscle is not present, it may be replaced by band of tissue called epitrochleoanconeus ligament

Forearm: Ulnar Nerve and Branches

- Passes behind medial epicondyle, enters forearm between humeral & ulnar heads of flexor carpi ulnaris (FCU)
- Courses distally between FCU & flexor digitorum profundus (FDP)
  - Supplies FCU, medial 1/2 of FDP
- Palmar cutaneous branch
  - Arises midforearm & supplies skin on ulnar 1/2 of palm
- Dorsal cutaneous branch
  - Arises distal forearm & supplies skin on ulnar side of dorsum hand
- Distally, becomes superficial & passes into wrist superficial to flexor retinaculum

Hand: Ulnar Nerve and Branches

- In Guyon canal, ulnar nerve lies radial to pisiform & at ulnar & dorsal aspect of ulnar artery
- Enters Guyon canal; small triangular-shaped fibroosseous tunnel
  - Floor = flexor retinaculum; ulnar wall = pisiform & hook of hamate; roof = fascia continuous with flexor retinaculum (superficial palmar ligament)
  - Contains ulnar artery & ulnar nerve
  - Nerve lies between ulnar artery & pisiform or hook of hamate
  - Divides at distal tunnel into superficial sensory branch & deep motor branch
    - Superficial branch; sensory to ulnar side of palm, little finger & ulnar 1/2 of ring finger
    - Deep branch lying medial to hook of hamate where prone to injury; motor to hypothenar muscles, all interossei, 3rd & 4th lumbricals, & adductor pollicis

ANATOMY IMAGING ISSUES

Imaging Recommendations

- Knowledge of nerve location & anatomic relationships is essential for sonographic identification
- Examination of nerves in transverse plane is preferable to longitudinal plane as it allows nerves to be followed continuously throughout limb

Imaging Approaches

- Ultrasound
  - Use of high-frequency 12-17 MHz transducer
  - Nerve echogenicity
    - Transverse scan: Irregularly dispersed hypoechoic dots, due to nerve fascicles separated by hyperechoic epineurium
    - Longitudinal scan: Parallel hypoechoic tracts of uniform caliber
    - Gain control & focus settings should be optimized for adequate visualization

Imaging Pitfalls

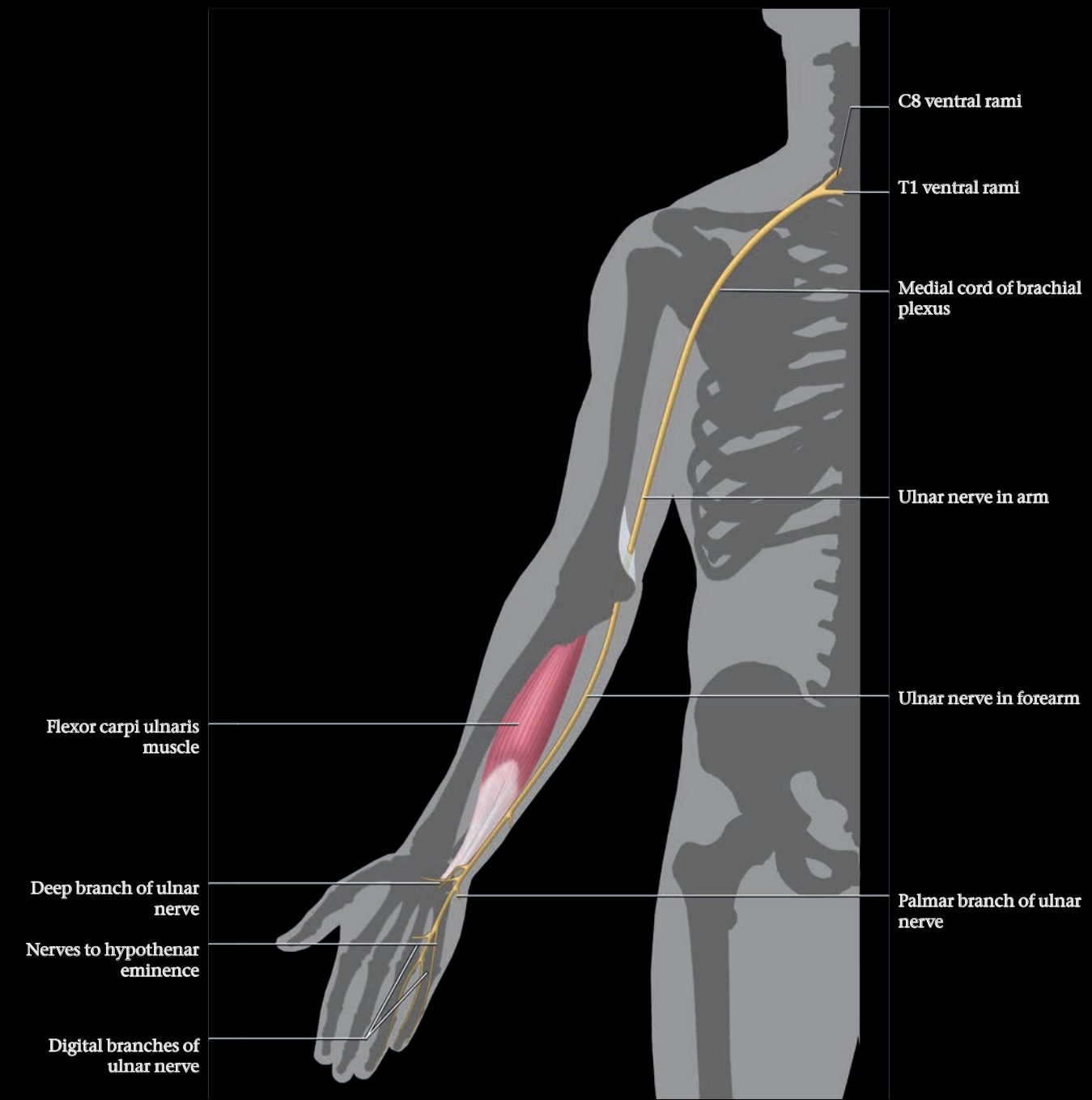
- Smaller nerves & nerve branches (1-2 mm) are difficult to identify & their location may only be inferred by adjacent vessels
- Anisotropy artifacts may affect scanning, especially in short axis
  - Tilting transducer during scanning helps to achieve best view
- Fixed structural causes of nerve compression are more easy to identify than functional structural compression
- Ulnar nerve normally swells to a mild degree in cubital tunnel though not as much as in cubital tunnel syndrome

CLINICAL IMPLICATIONS

Clinical Importance

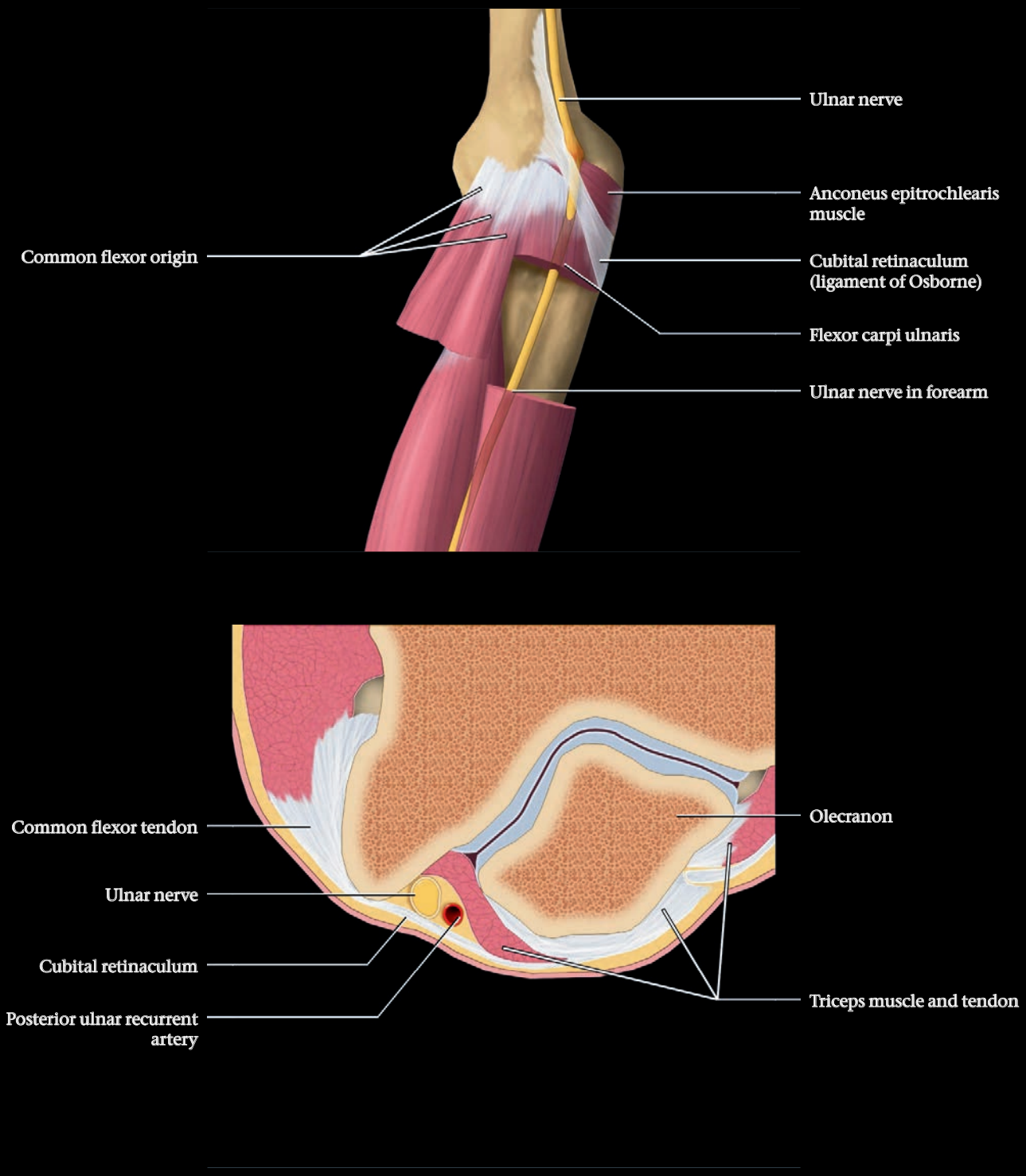
- Direct sonographic visualization of nerves can reveal a focal abnormality or injury, differentiate from extraneural tumor, and show extent of lesion & relationship to adjacent structures & vessels
- Ulnar nerve prone to compression in cubital tunnel, between humeral and ulnar origins of FCU & in Guyon canal
  - Cubital tunnel syndrome = compression of nerve in cubital tunnel
    - Mostly idiopathic without structural cause being found
    - Nerve swelling in cubital tunnel
    - Measure nerve caliber proximal to, within, & distal to cubital tunnel
    - Compare with opposite side
  - Guyon canal compression is often structural
    - Due to ganglion cyst at Guyon canal from pisotriquetral joint, fracture hook of hamate or nerve sheath tumor
    - Other causes are occupational neuritis, ulnar artery aneurysm, anomalous muscle, lipoma, laceration, or giant cell tumor of tendon sheath
- Dislocation of ulnar nerve over medial epicondyle can be observed on ultrasound during elbow flexion
  - ± dislocation of medial triceps muscle belly
  - Repeated dislocation of ulnar nerve may lead to ulnar neuritis, functional impairment, and symptoms of cubital tunnel syndrome

GRAPHIC, ULNAR NERVE



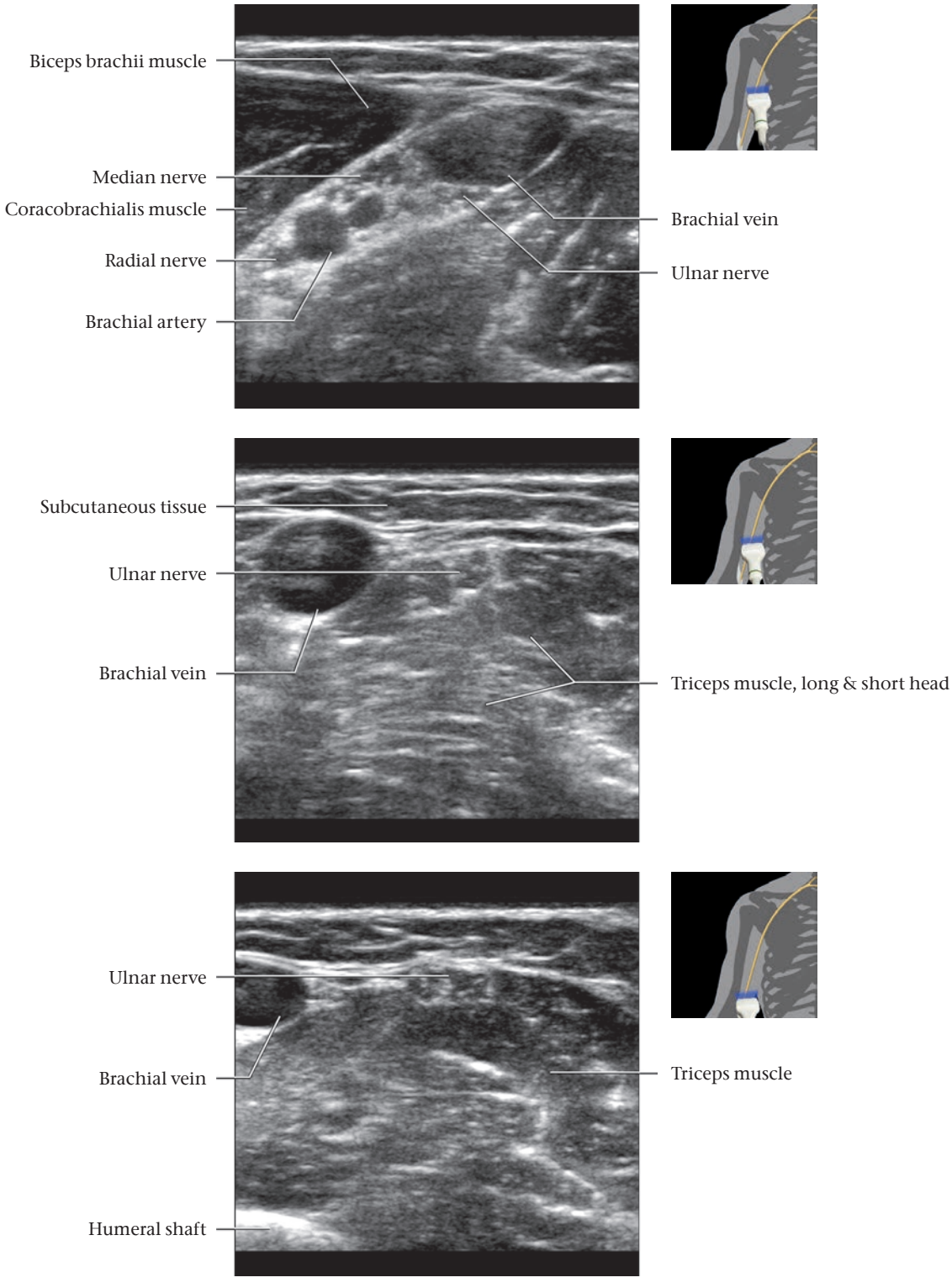
Graphic shows the course of the ulnar nerve. The ulnar nerve arises from the medial cord of the brachial plexus (C8, T1). It is located posteromedially, deep to the triceps muscles in the distal arm, where it passes posterior to medial epicondyle in the cubital tunnel (cubital syndrome due to compression of ulnar nerve in cubital tunnel). The ulnar nerve may sublux anterior to the medial epicondyle in about 15% of normal people, usually during flexion. The ulnar nerve passes behind the medial epicondyle, entering the forearm between the humeral and ulnar heads of flexor carpi ulnaris (FCU). The ulnar nerve then courses distally between FCU and the flexor digitorum profundus (FDP) muscles, supplying the flexor carpi ulnaris muscle and medial 1/2 of the FDP muscle.

GRAPHICS, CUBITAL TUNNEL



(Top) *Medial graphic shows the cubital tunnel. The anconeus epitrochlearis is an inconstant accessory muscle that lies superficial to the ulnar nerve and may compress the nerve against the medial epicondyle.* ***(Bottom)*** *Axial graphic shows the cubital tunnel. The ulnar nerve may be compressed within the cubital tunnel (cubital tunnel syndrome) by a mass, synovitis, post-traumatic osseous deformity, or aneurysm of the recurrent ulnar artery. The ulnar nerve may sublux out of the cubital tunnel aided by the adjacent medial head of the triceps. Recurrent subluxation, which can be found in about 15% of asymptomatic subjects, can lead to ulnar neuritis, which can produce similar symptoms to ulnar nerve compression.*

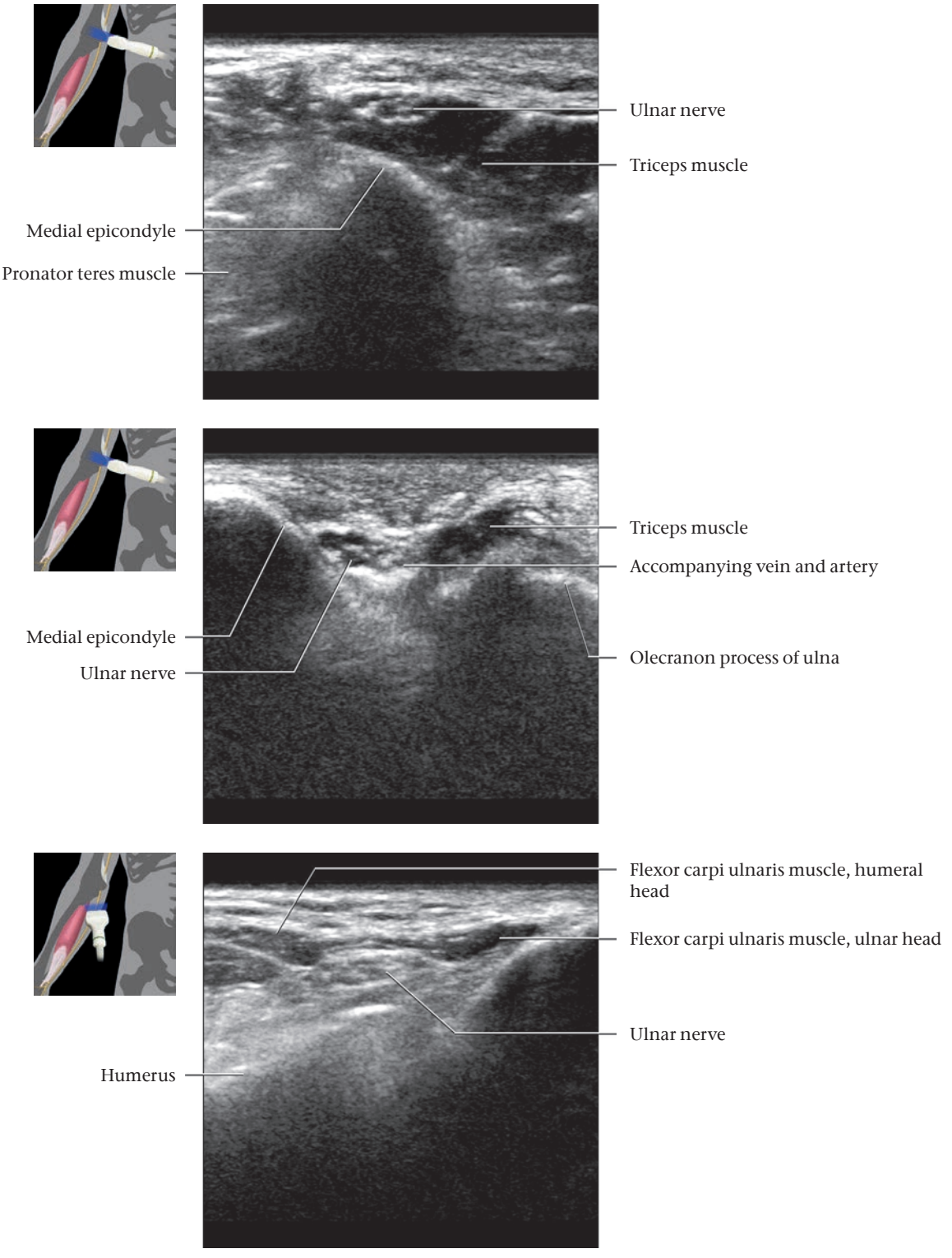
TRANSVERSE US, ARM



(Top) *Transverse grayscale ultrasound shows the ulnar nerve at the proximal arm. The ulnar nerve arises from the medial cord of the brachial plexus and lies just medial to the brachial vein.* ***(Middle)*** *Transverse grayscale ultrasound shows the ulnar nerve at the midarm. The ulnar nerve pierces the medial intermuscular septum in the midarm where it may be potentially compressed. The ulnar nerve gives off no branch in the arm.* ***(Bottom)*** *Transverse grayscale ultrasound shows the ulnar nerve in the distal arm. The ulnar nerve runs distally on the surface of the triceps muscle to reach the area between the olecranon and the medial epicondyle, i.e., the cubital tunnel.*

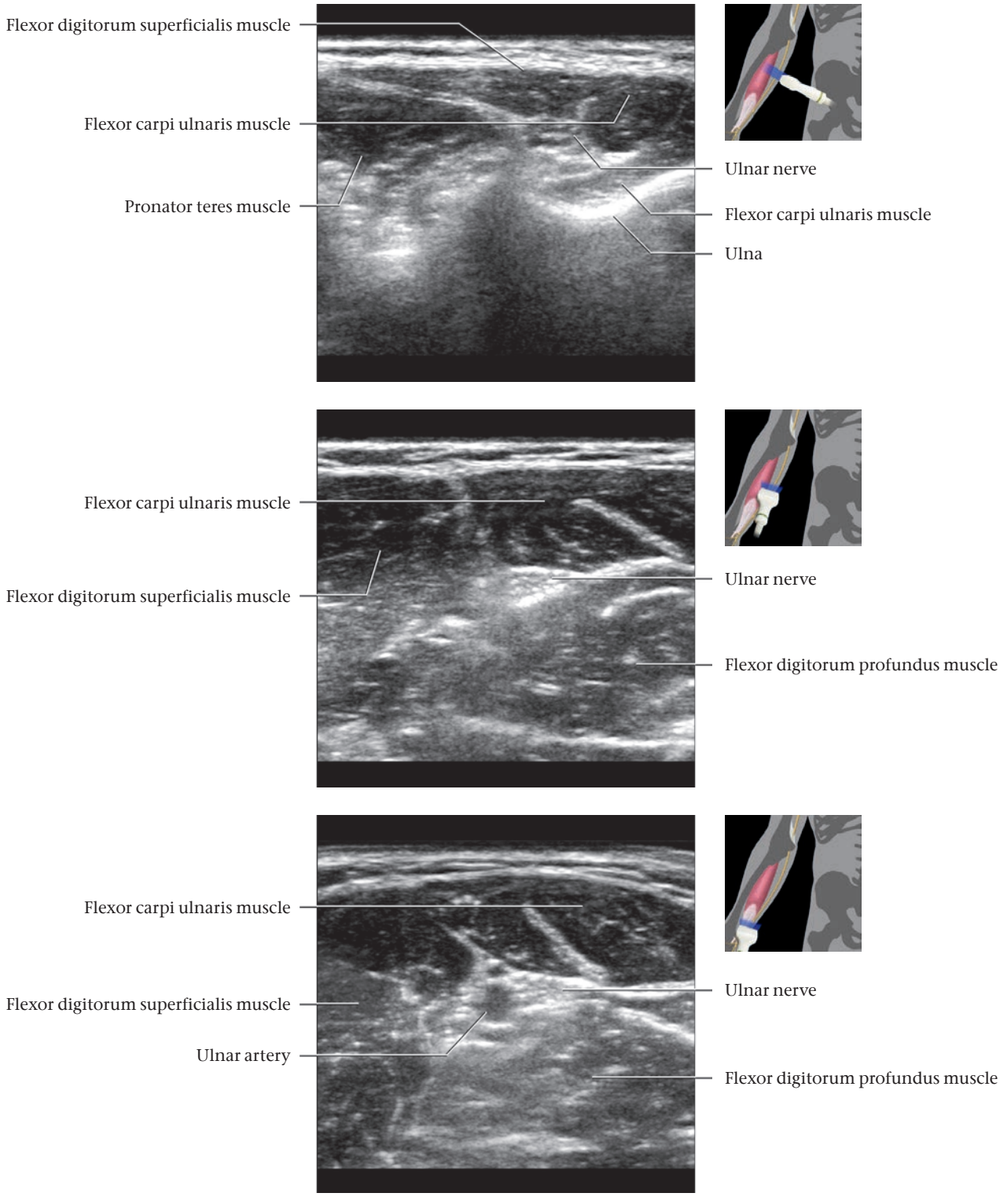
ULNAR NERVE

TRANSVERSE US, CUBITAL TUNNEL



(Top) *Transverse grayscale US shows the ulnar nerve just proximal to the cubital tunnel. The cubital tunnel is the most common site of ulnar neuropathy. Neuropathy may take the form of compression from the overlying retinaculum or fibrous bands, bony impingement & tumors, subluxation of the ulnar nerve over the medial epicondyle, or direct injury.* ***(Middle)*** *Transverse grayscale US shows the ulnar nerve at the cubital tunnel. The cubital tunnel retinaculum (formed from an extension of investing fascia of the flexor carpi ulnaris & the ligament of Osborne) forms the roof of the cubital tunnel. The retinaculum is 4 mm wide & difficult to depict on ultrasound. The floor & wall of cubital tunnel are formed by containing bones, elbow capsule, & the medial collateral ligament. The ulnar nerve normally enlarges slightly within the cubital tunnel.* ***(Bottom)*** *Transverse grayscale ultrasound shows the ulnar nerve just beyond the cubital tunnel.*

TRANSVERSE US, FOREARM

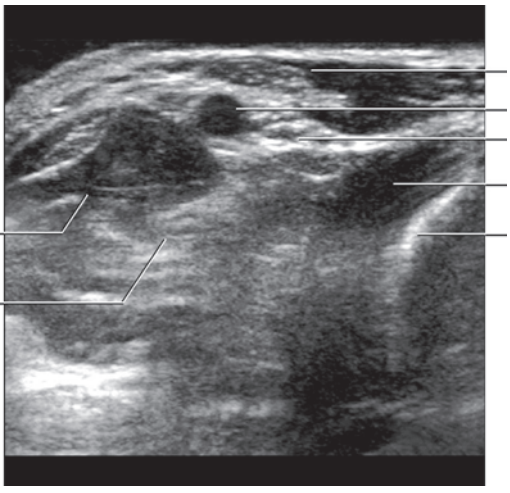


(Top) *Transverse grayscale ultrasound shows the ulnar nerve just beyond the cubital tunnel, where the ulnar nerve passes between the 2 heads (humeral and ulnar) of the flexor carpi ulnaris tendon. This is a potential site of compression.* ***(Middle)*** *Transverse grayscale ultrasound shows the ulnar nerve in the midforearm. The ulnar nerve pierces the intermuscular septum, dividing the flexor and extensor compartments of the forearm to descend in the flexor compartment between flexor carpi ulnaris and flexor digitorum profundus muscles.* ***(Bottom)*** *Transverse grayscale ultrasound shows the ulnar nerve in the distal forearm. The ulnar nerve is joined on its radial side by the ulnar artery in the distal forearm, and the 2 structures travel to the wrist, deep to the flexor carpi ulnaris muscle.*

ULNAR NERVE

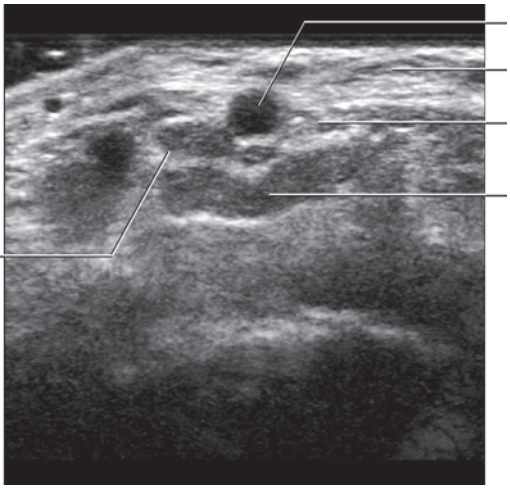
TRANSVERSE AND LONGITUDINAL US, WRIST AND FOREARM





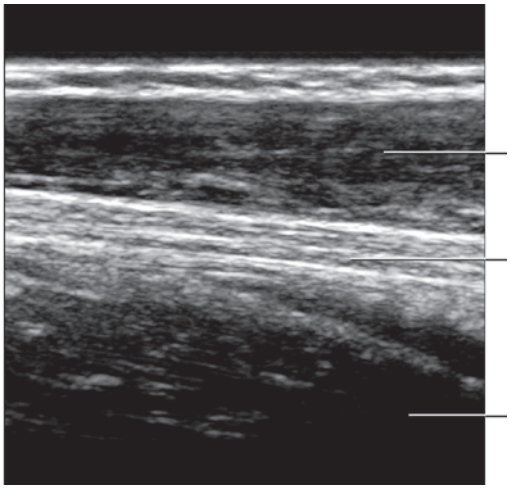
Flexor carpi ulnaris muscle
Ulnar artery
Ulnar nerve
Pronator quadratus muscle
Ulna
Flexor digitorum superficialis muscle
Flexor digitorum profundus muscle





Ulnar artery
Flexor carpi ulnaris tendon
Ulnar nerve
Flexor digitorum profundus muscle
Flexor digitorum superficialis tendon

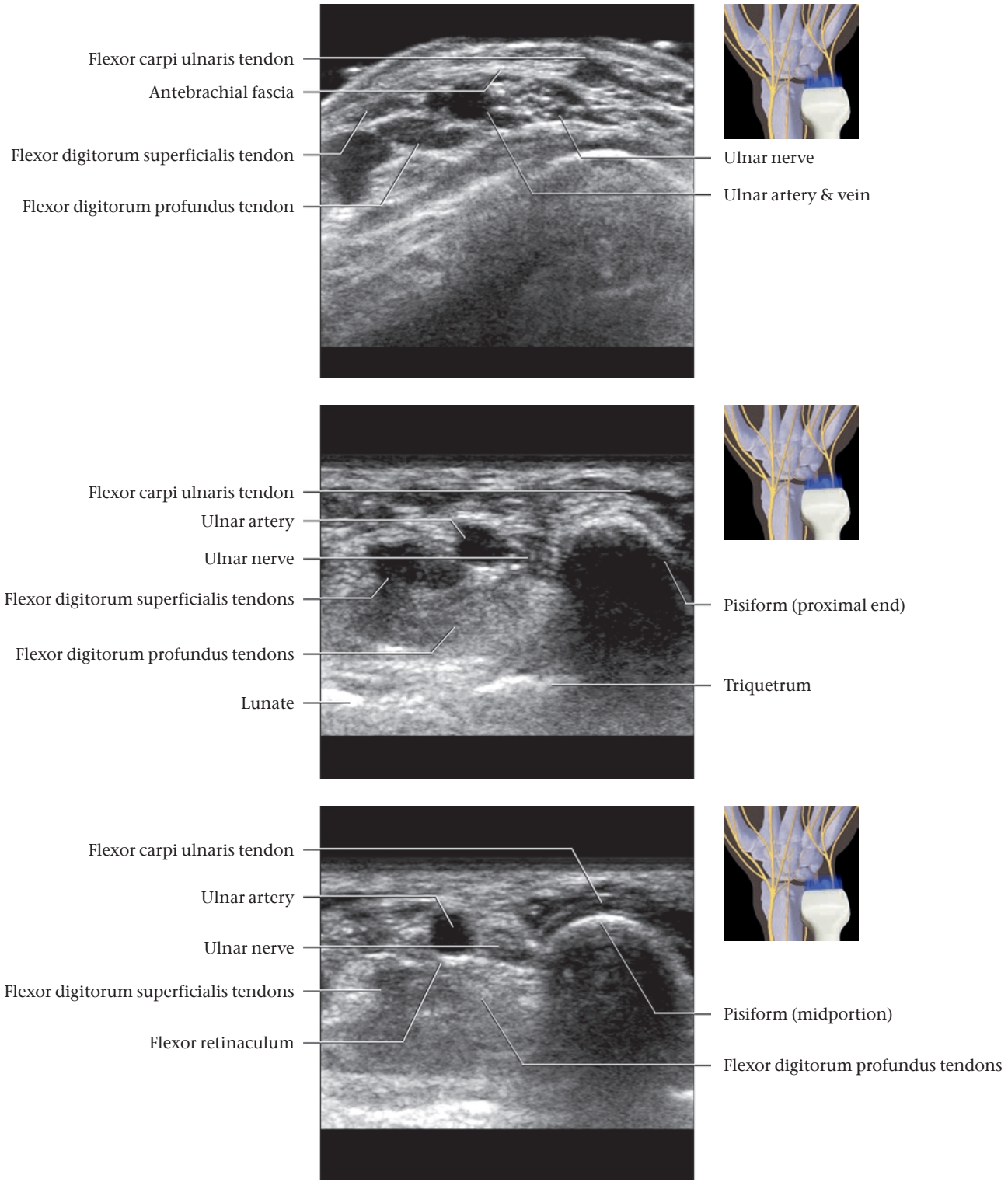




Flexor carpi ulnaris muscle
Ulnar nerve
Flexor digitorum profundus muscle

(Top) *Transverse grayscale ultrasound shows the ulnar nerve at the distal forearm. The ulnar nerve can be identified by 1st visualizing the ulnar artery and then identifying the nerve just ulnar to the artery.* ***(Middle)*** *Transverse grayscale ultrasound shows the ulnar nerve just proximal to the wrist. At this location, the ulnar nerve is prone to injury from dog-bite, penetrating injury, and nonaccidental self injury.* ***(Bottom)*** *Longitudinal grayscale ultrasound shows the ulnar nerve at the distal 1/3 of the forearm. Note the fibrillar pattern of the nerve with a mixed hypoechoic and hyperechoic pattern due to hypoechoic nerve fascicles separated by hyperechoic epineurium.*

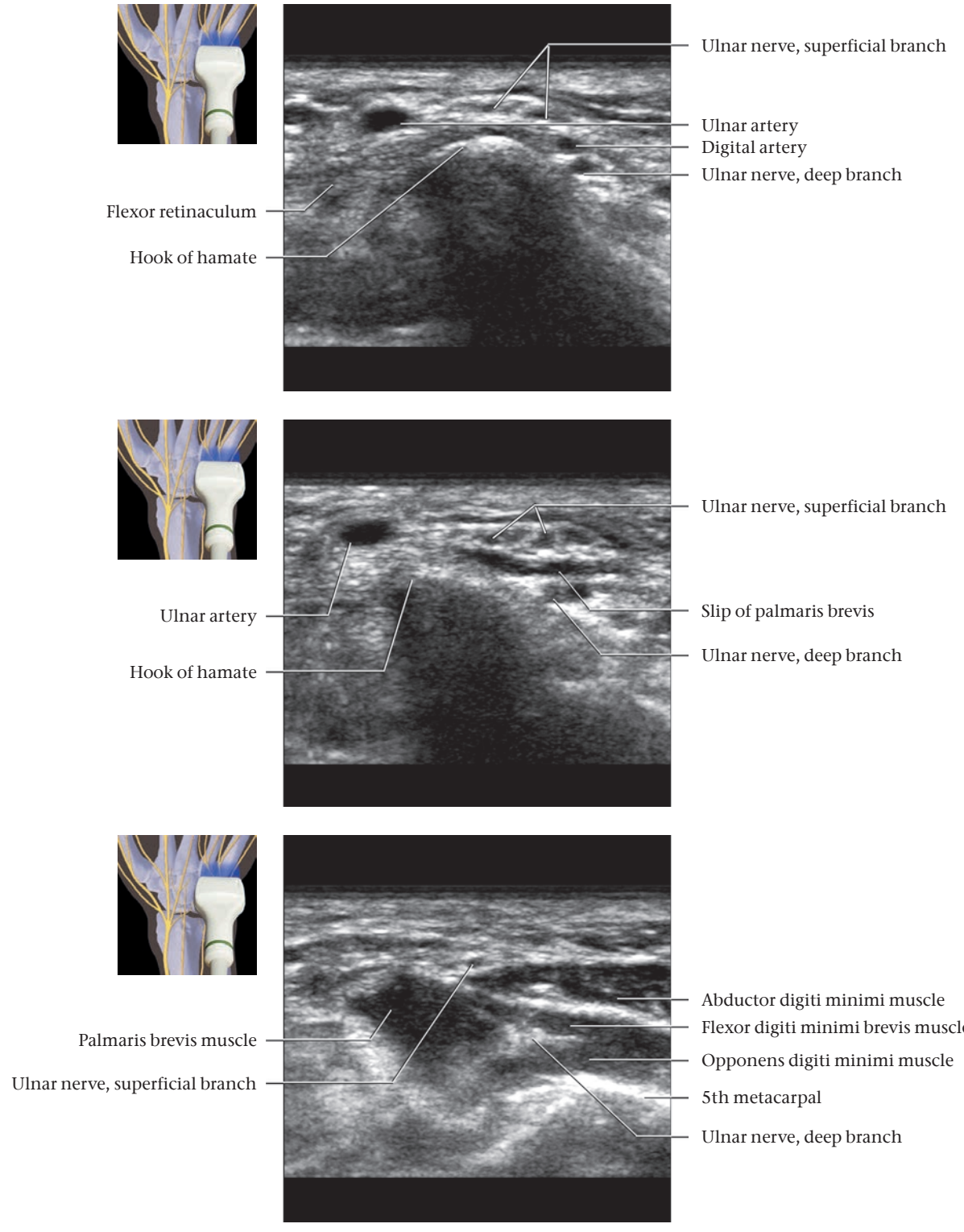
TRANSVERSE US, GUYON CANAL



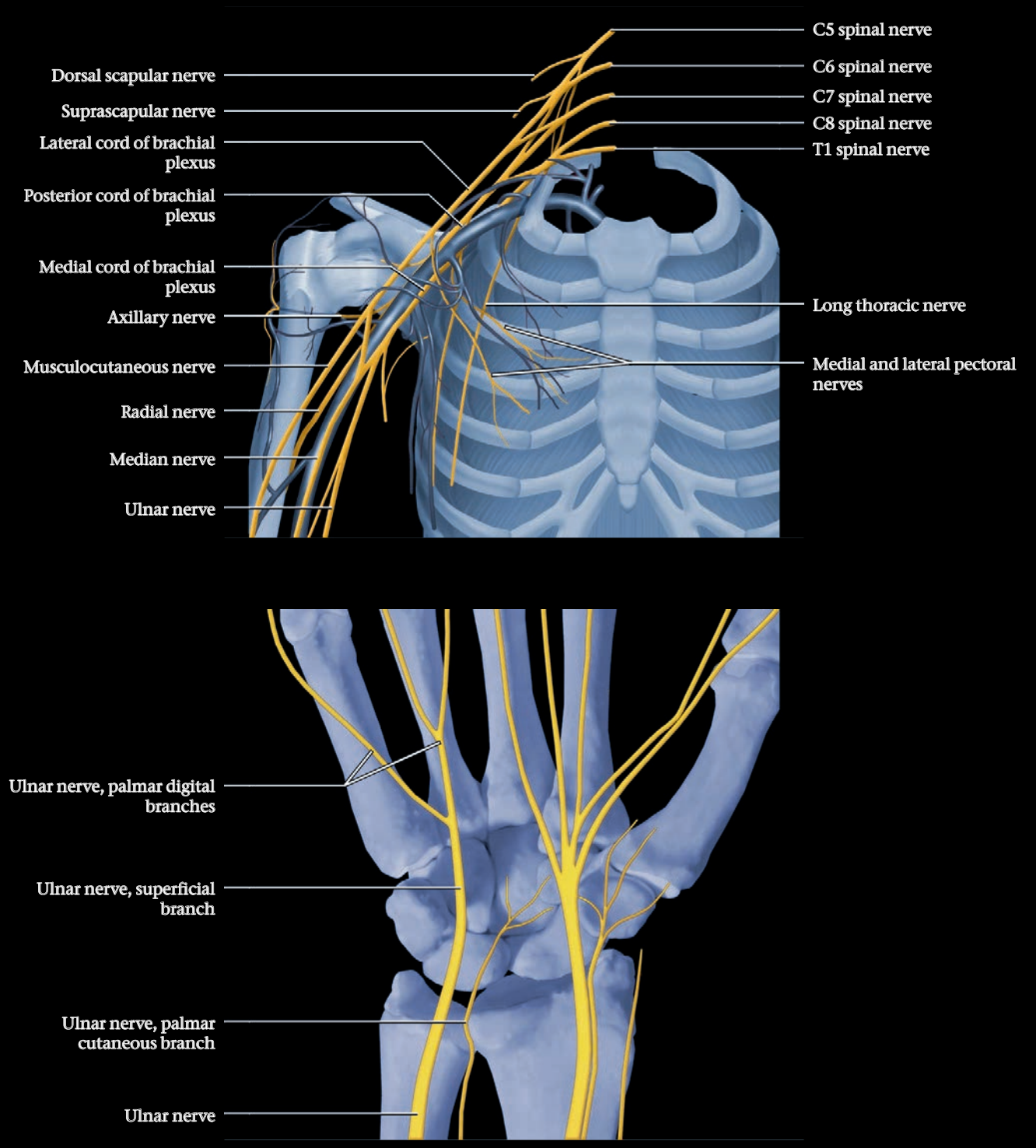
(Top) *Transverse grayscale ultrasound shows the ulnar nerve just proximal to the Guyon canal.* ***(Middle)*** *Transverse grayscale ultrasound shows the ulnar nerve at the proximal end of Guyon canal. Guyon canal is the 2nd most common site of ulnar neuropathy.* ***(Bottom)*** *Transverse grayscale ultrasound shows the ulnar nerve at the proximal end of Guyon canal. Ganglia arising from the pisiform-triquetral articulation are the most common cause of ulnar nerve compression in the Guyon canal.*

ULNAR NERVE

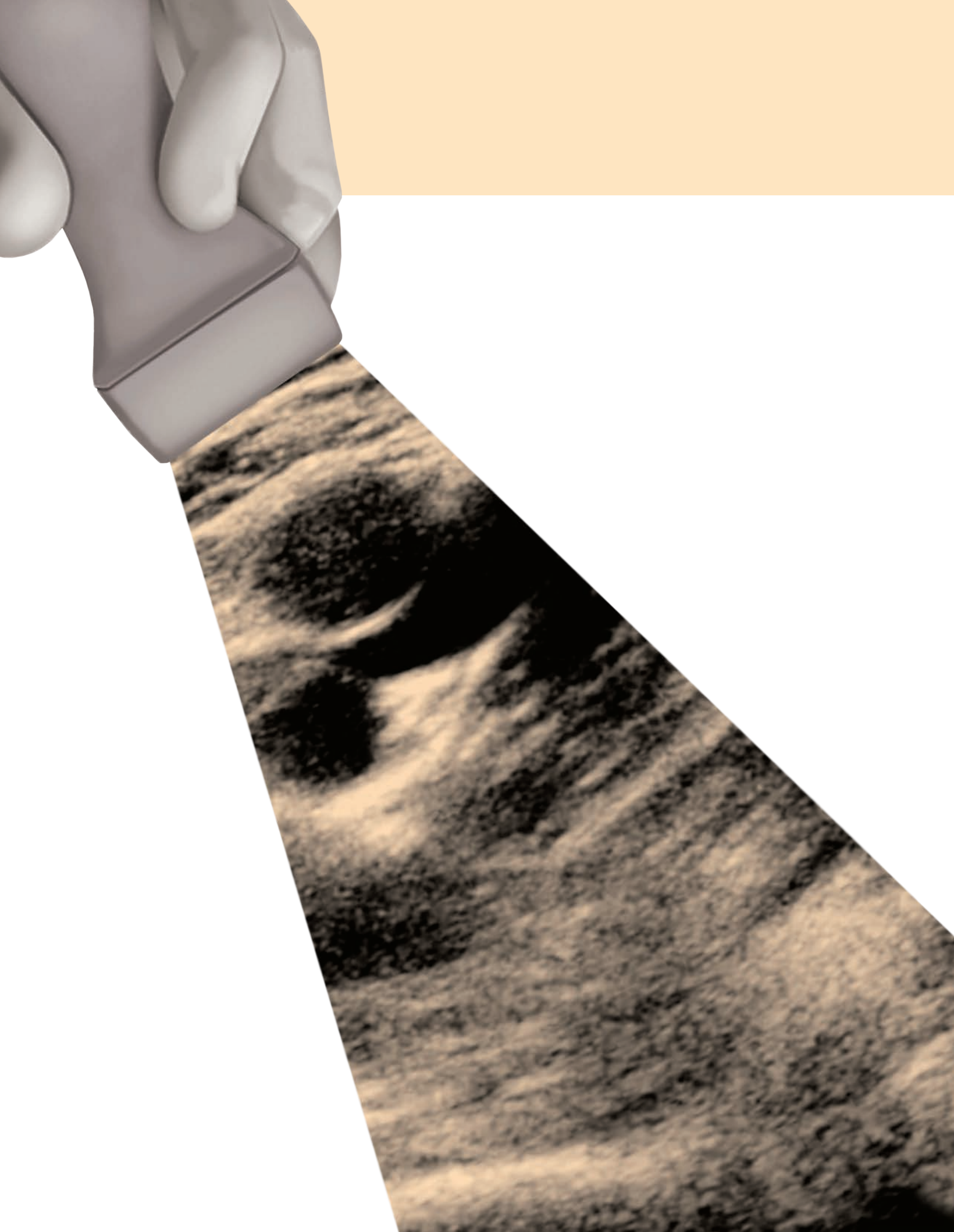
TRANSVERSE US, DISTAL TO GUYON CANAL



(Top) *Transverse grayscale ultrasound shows the ulnar nerve at the distal end of Guyon canal, where the ulnar nerve divides into superficial and deep branches. These pass close to the top of (superficial branch) and side of (deep branch) the hook of hamate.* ***(Middle)*** *Transverse grayscale ultrasound shows the ulnar nerve at the distal end of the hook of hamate level. Hook of hamate fractures (common in golfers, baseball players) and repeated blunt trauma ("handle bar" palsy) may injure the ulnar nerve as it passes by the hook of hamate. The ulnar artery can be injured at this location as well (hypothenar hammer syndrome).* ***(Bottom)*** *Transverse grayscale ultrasound shows the ulnar nerve at the base of the hypothenar muscles. The superficial branch of the ulnar nerve stays superficial to supply the skin, while the deep branch stays deep to supply the hypothenar muscles & the 3rd & 4th lumbrical muscles.*



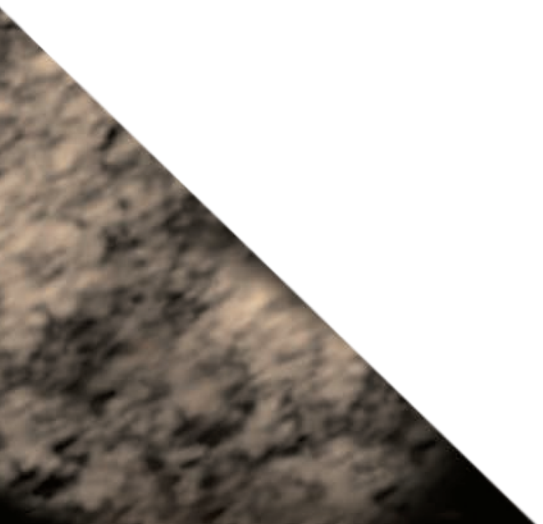
(Top) *Anterior graphic shows the brachial plexus.* ***(Bottom)*** *Ulnar nerve supplies the ulnar wrist and hand. In addition to the branches shown, a dorsal branch of the ulnar nerve passes between the flexor carpi ulnaris and ulna about 5 cm proximal to the wrist to supply the dorsal ulnar wrist and the little finger. Deep and superficial branches supply motor and sensory branches to the hypothenar eminence.*



SECTION 2

Lower Limb

Hip **I**-2-2
Thigh Muscles **I**-2-12
Femoral Vessels and Nerves **I**-2-24
Knee **I**-2-38
Leg Muscles **I**-2-56
Leg Vessels **I**-2-68
Leg Nerves **I**-2-84
Ankle **I**-2-88
Tarsus **I**-2-106
Foot Vessels **I**-2-120
Metatarsals and Toes **I**-2-126



HIP

IMAGING ANATOMY

Overview
- Ball and socket joint with wide range of motion 2nd only to glenohumeral joint

Acetabulum
- Formed by pubis, ilium, ischium
- Oriented anterior, inferior, lateral
- Covers > 50% femoral head
- **Anterior and posterior rims**: Osseous margins of acetabulum
- **Medial wall**: Quadrilateral plate ilium

Femoral Head
- 2/3 of sphere
- Covered by articular cartilage
  - Cartilage thickest superiorly
  - Cartilage thins at head/neck junction

Labrum
- Fibrocartilage lip deepens acetabular rim
- Joins transverse ligament at margins of acetabular notch
- Thickest posteriorly and superiorly
- Widest anteriorly and superiorly
- Vascular supply: Branches of obturator, superior, and inferior gluteal arteries
  - Mainly capsular surface
- Shape
  - Triangular in 66-94%
  - Variants: Rounded/blunt or absent
  - Absent labra: Constellation absent anterior labrum and small remnant superiorly
    - In 10-14% asymptomatic individuals
- Function
  - Protect cartilage: Distributes forces by maintaining synovial fluid layer between articular surfaces
  - Prevents lateral translation femoral head
- Labral tear
  - Frequently has associated paralabral ganglion/cyst
  - Easier to detect in presence of joint effusion/arthrographic contrast
  - More common anterosuperiorly and anteriorly

Joint Capsule
- 2 layers: Internal synovial and external fibrous (not usually separable on imaging)
  - External layer forms capsular ligaments
- Attachments
  - Acetabulum
    - Base of labrum anteriorly and posteriorly
    - Several millimeters above labrum superiorly
  - Femur
    - Anterior: Intertrochanteric line
    - Posterior: Proximal to intertrochanteric crest
    - Anterior attachment more lateral than posterior attachment
  - **Perilabral recess**: Between labrum and capsule
    - Smaller anteriorly and posteriorly
    - Larger superiorly

Vascular Supply
- Branches of medial and lateral circumflex femoral, deep division of superior gluteal, inferior gluteal arteries, artery of ligamentum teres (branch of obturator artery)

Innervation
- Branches from nerve to rectus femoris, nerve to quadratus femoris, anterior division obturator nerve, accessory obturator nerve, superior gluteal nerve

Major Adjacent Structures
- **Greater trochanter**
  - Insertion
    - Gluteus minimus and medius muscles
    - Gluteus minimus to anterior facet
    - Gluteus medius to lateral and posterosuperior facets
  - Separated from overlying iliotibial tract by thin trochanteric bursa (normally barely perceptible on imaging)
- **Lesser trochanter**
  - Insertion
    - Iliopsoas muscle
- **Anterior inferior iliac spine**
  - Origin
    - Rectus femoris muscle
- **Iliopsoas muscle**
  - Run inferomedially across anterior surface of hip joint
- **Femoral vessels**
  - Separated from hip joint by iliopsoas muscle

Neonatal Hip
- High success rate in treatment of developmental dysplasia demands early imaging diagnosis (with ultrasound)
- Established measurements of bony and cartilaginous components for comparison with normal reference
- Main measurements reflect depth of acetabulum and acetabular coverage of femoral head

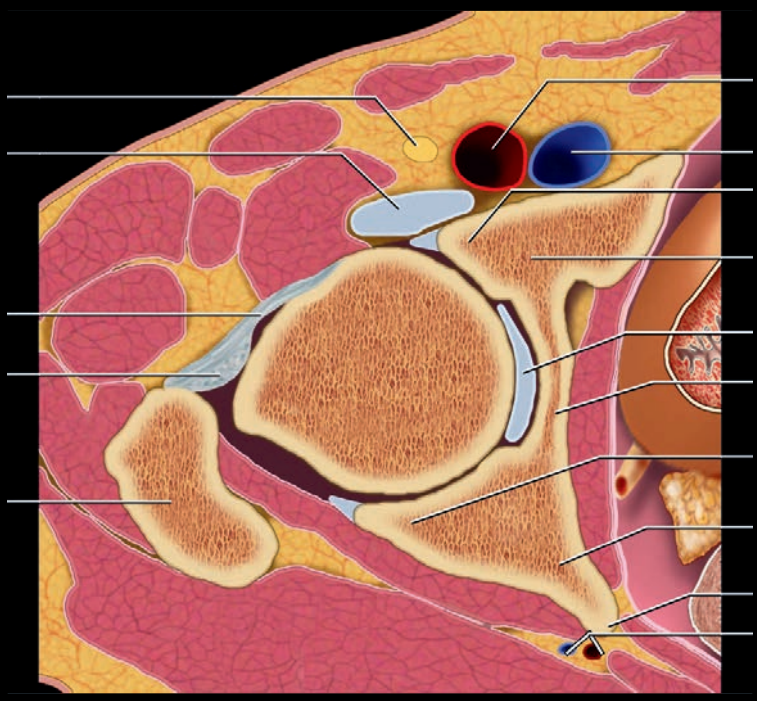
ANATOMY IMAGING ISSUES

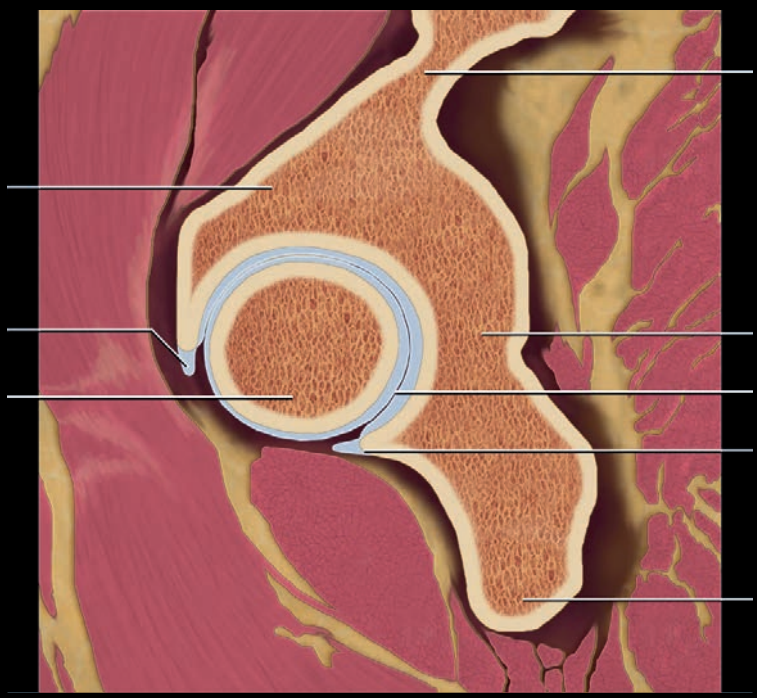
Imaging Recommendations
- Radiographs for assessing osseous alignment
- Ultrasound for joint effusion and surrounding soft tissue
  - Also used for real-time guided procedures: Hip joint or abscess aspiration/biopsy; intraarticular contrast injection
  - Ideal in neonates for suspected developmental hip dysplasia
- MR arthrography preferred to assess intraarticular structures

Imaging Sweet Spots
- Small joint effusions are best detected on ultrasound by a hypoechoic thickening/layer over anterior surface of femoral neck
  - Best site for aspiration/injection
- Paralabral ganglion cysts should alert physician to presence of labral tear

Imaging Pitfalls
- Synovial proliferation usually shows no evidence of vascularity on color Doppler scanning and is therefore difficult to distinguish from an effusion

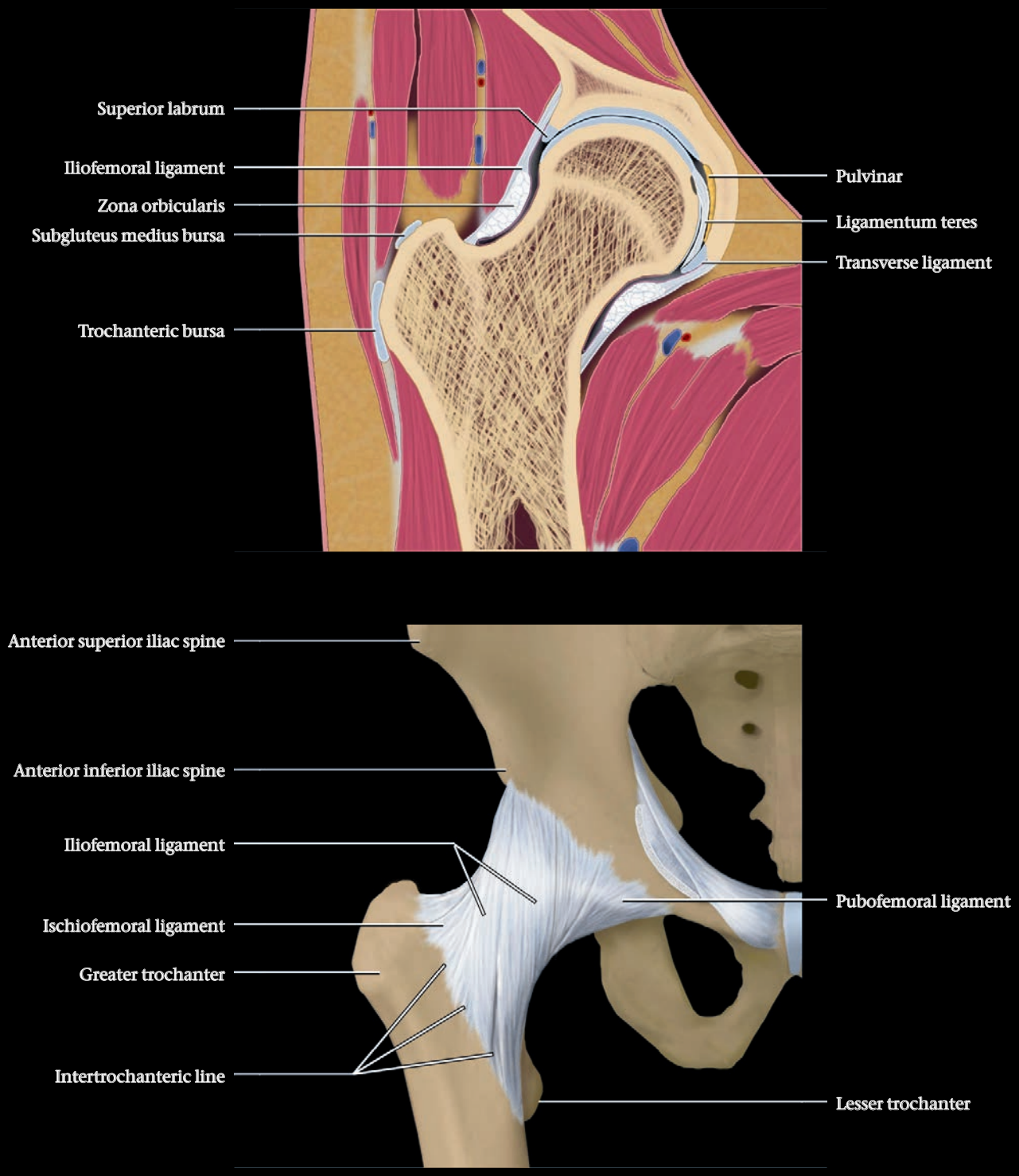
GRAPHICS, AXIAL & SAGITTAL HIP SECTIONS





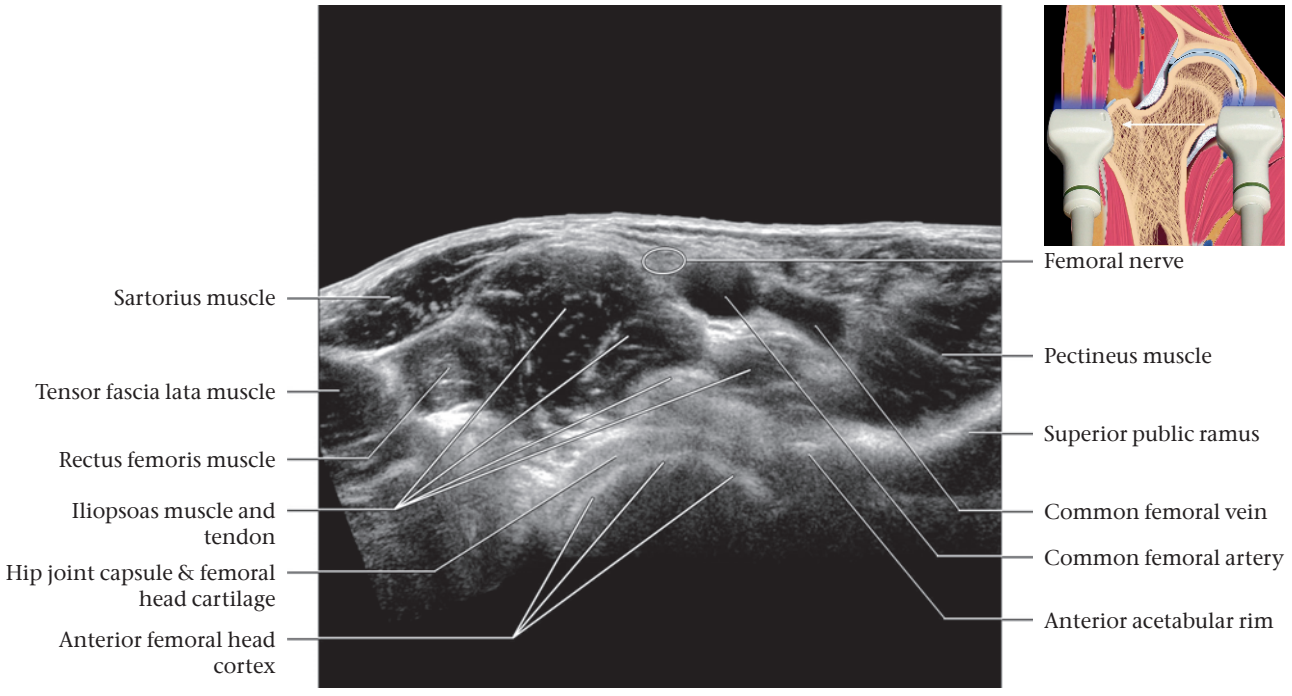
*(**Top**) Axial graphic representation shows the hip joint. The iliopsoas bursa is closely approximated to the joint anteriorly. The ligamentum teres is seen in profile as a flattened structure. The 2 layers of the external capsule, the more superficial longitudinal fibers and deep circular fibers, are visible. (**Bottom**) Sagittal representation of the hip joint nicely demonstrates the inverted Y of the acetabulum. The ilium is the stem and the limbs are the anterior and posterior acetabular columns.*

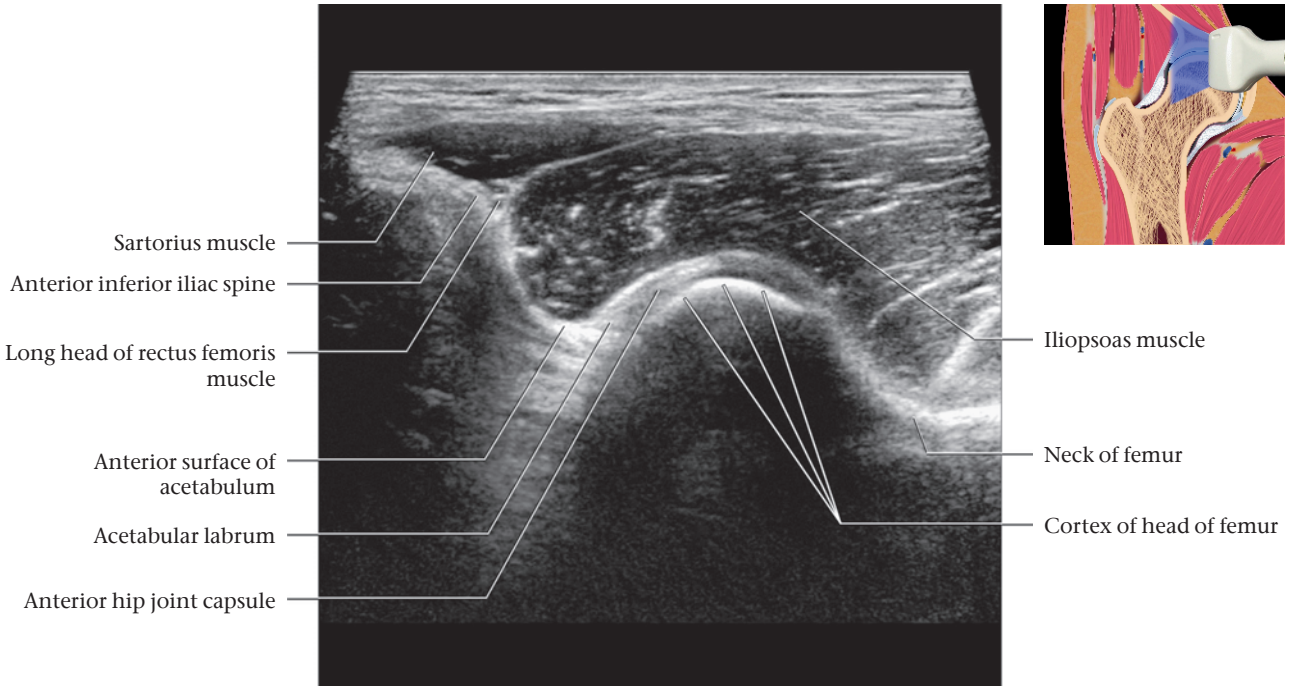
GRAPHICS, CORONAL HIP SECTION & LIGAMENTS



(Top) *This coronal image demonstrates many of the important structures of the hip joint. The longitudinally oriented fibers of the ligaments of the external joint capsule and the deeper circularly oriented fibers of the zona orbicularis are visible. Note the long axis of the ligamentum teres and its insertion onto the transverse ligament. The pulvinar fills the acetabular fossa.* ***(Bottom)*** *Anterior ligaments are shown. The longitudinal spiral of the iliofemoral and pubofemoral ligaments is well seen with attachments to the anterior inferior iliac spine and pubic aspect of the obturator foramen, respectively. The ischiofemoral ligament wraps over the superior aspect of the femoral neck to attach to the anterior femoral neck.*

HIP OVERVIEW

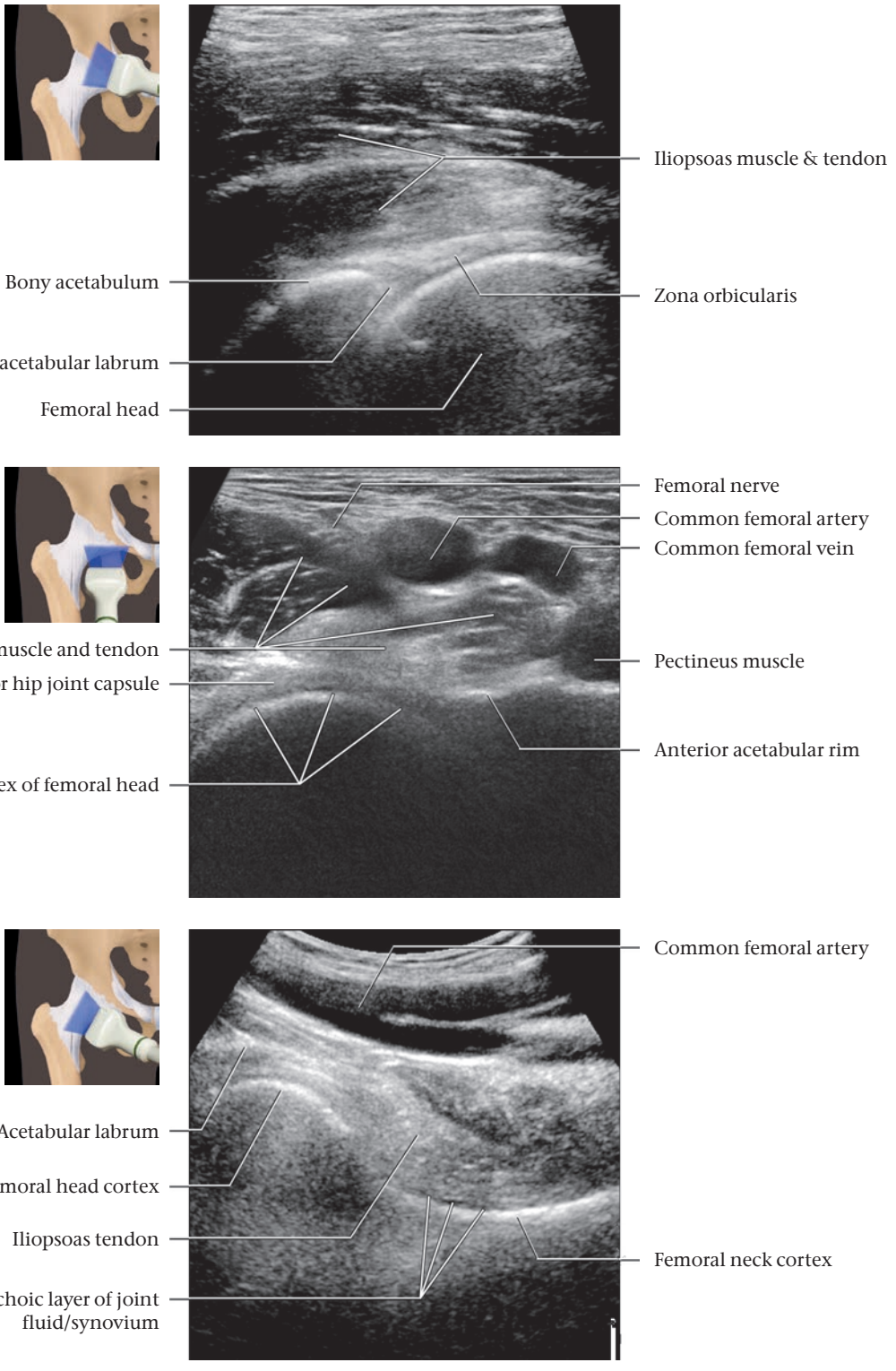




(Top) *Transverse panoramic scan shows the femoral head. Medially & superiorly, the femoral head is covered by bony acetabulum and not visible with ultrasound. Laterally, the hip joint lies deep to the iliopsoas muscle & femoral triangle. Further laterally, the hip joint is associated with the gluteal muscles.* ***(Bottom)*** *Oblique sagittal scan shows hip joint & anterior inferior iliac spine. The acetabular labrum, which is thickest and widest anteriorly, can be seen between the acetabular rim & joint capsule. Small joint effusions are 1st detected not over the femoral head, but over the femoral neck as a hypoechoic layer. The femoral neck's relatively safe access makes it a suitable site for guided aspiration/injection.*

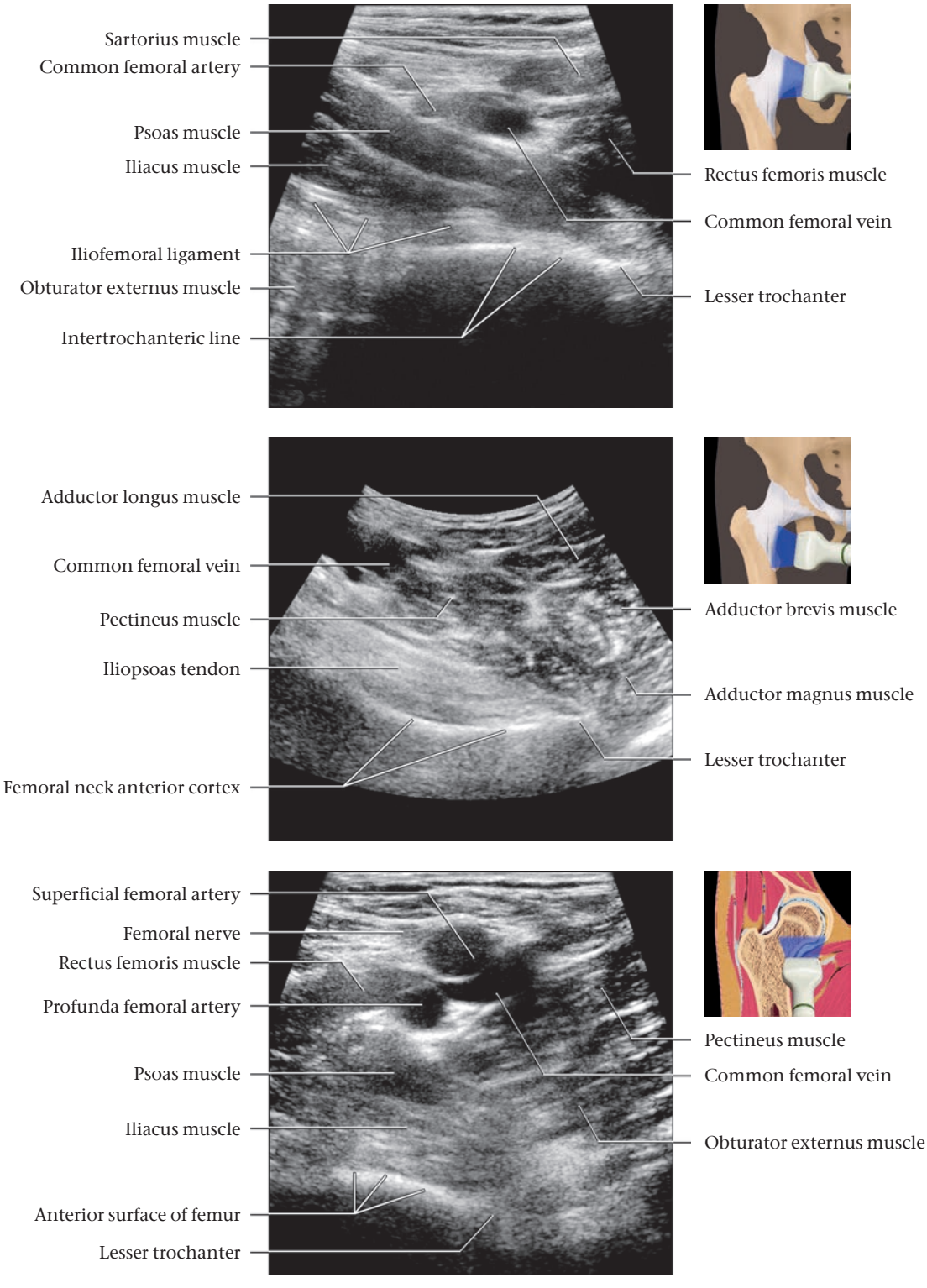
HIP

ACETABULUM



(Top) *Oblique sagittal scan along axis of femoral neck shows the triangular cross section of anterior acetabular labrum. Joint effusion/contrast tends to allow better delineation of its contour & lesions.* ***(Middle)*** *Transverse scan is shown at the level of the hip joint. Anterior femoral cortex/cartilage, hip joint capsule, & acetabular rim are well visualized. The contents of the femoral triangle are separated from the hip joint by the iliopsoas muscle and tendon, which explains why paralabral cysts may tract along the iliopsoas muscle.* ***(Bottom)*** *Effusions are 1st detected not over the femoral head but over the femoral neck as an increase in the normally minimal hypoechoic layer of joint fluid and synovium. This is also the safest site for joint injections (intraarticular contrast or medication).*

ILIOPSOAS INSERTION

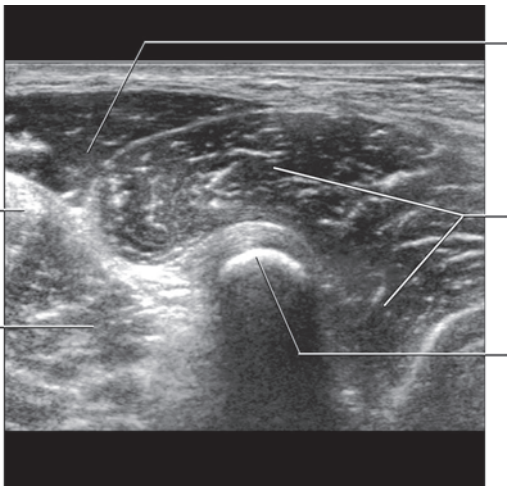


(Top) *Oblique sagittal scan along the course of the iliopsoas muscle is shown. Resolution is reduced due to depth of structures, which may be partially improved by externally rotating hip to bring deep structures closer to surface.* ***(Middle)*** *Oblique sagittal scan is shown slightly more distal than previous image. Insertion of iliopsoas tendon is at lesser trochanter, which may be avulsed in injury. Notice the close relationship between these structures and the adductor compartment.* ***(Bottom)*** *Transverse scan shows distal iliopsoas tendon just before insertion. A functional division is present between the hip flexor (iliopsoas) & hip adductors. This is also the apex level of the femoral triangle where superficial & profunda vessels bifurcate.*

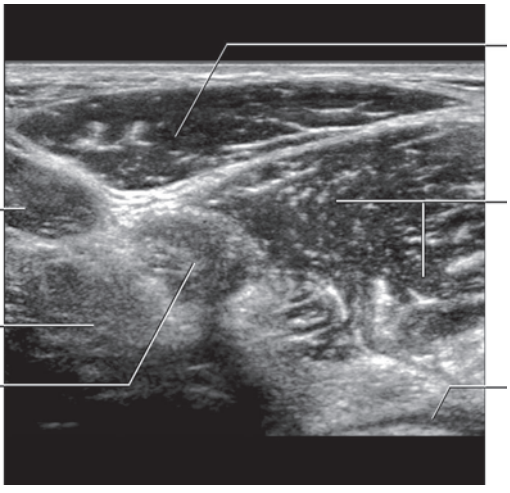
HIP

ANTERIOR INFERIOR ILIAC SPINE

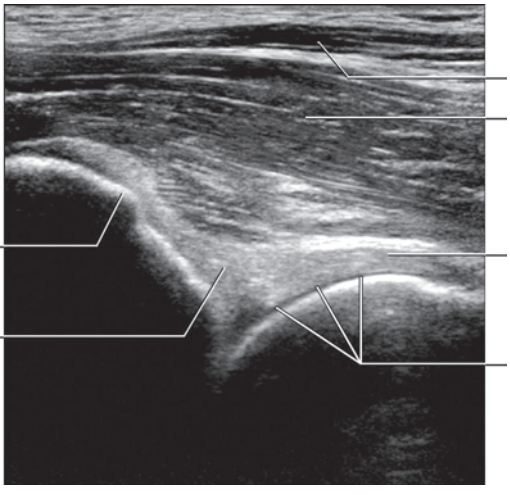






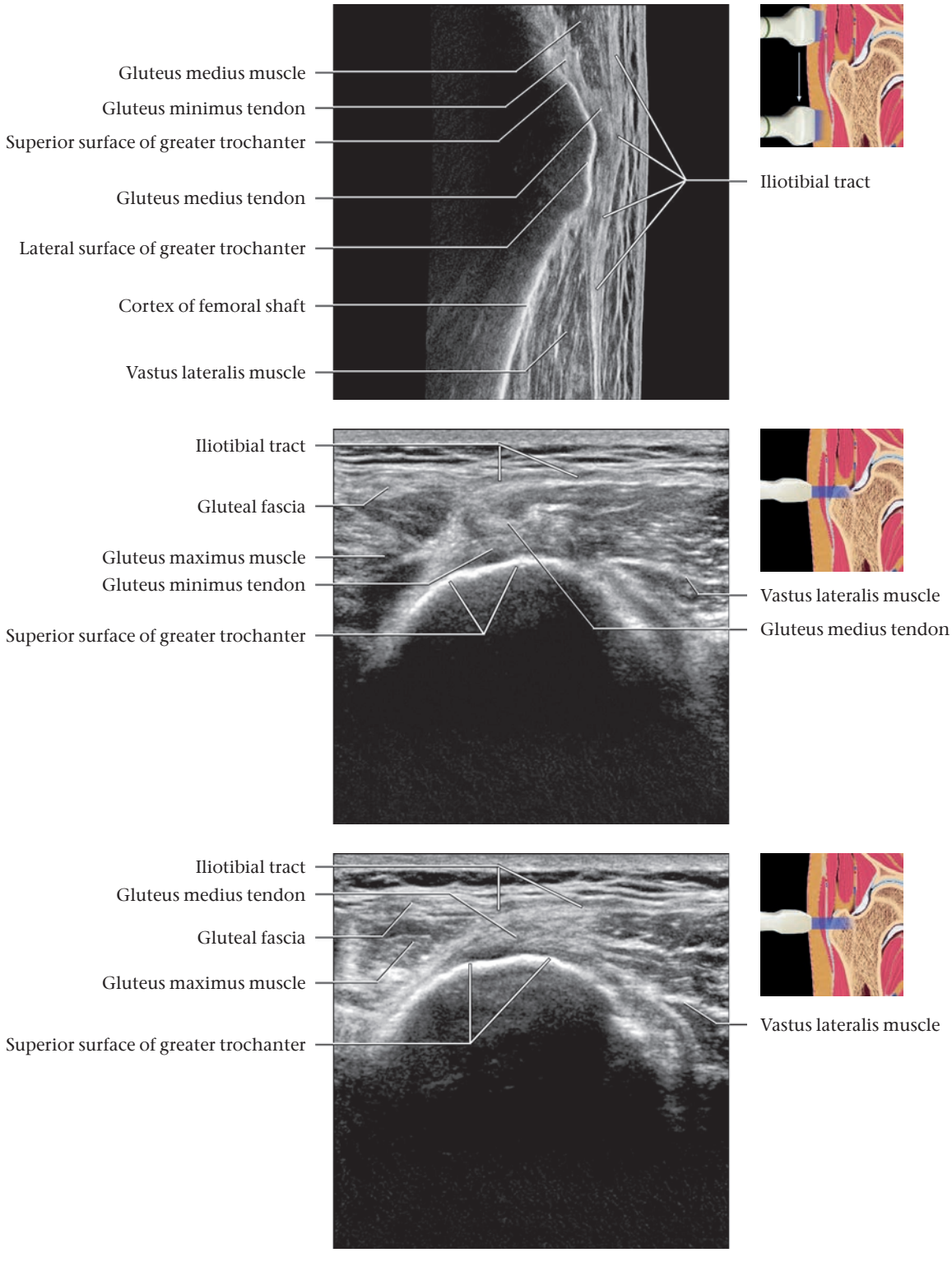






(Top) *Transverse scan through anterior inferior iliac spine, the rectus femoris muscle together with the sartorius muscle (which originates from anterior superior iliac spine) & the iliopsoas muscle (which originates from iliac fossa & lumbar transverse processes) form the hip flexors that cross the hip joint.* ***(Middle)*** *Transverse scan more inferior to previous image shows the long head of the rectus femoris muscle running deep to the sartorius muscle and lateral to the iliopsoas muscle. Note that the rectus muscle is the only quadriceps muscle that crosses the hip joint and thus acts as both hip flexor and knee extensor.* ***(Bottom)*** *Oblique scan along the sartorius muscle at hip joint level shows it to be roughly parallel with the iliopsoas muscle. The rectus femoris lies in a more lateral plane.*

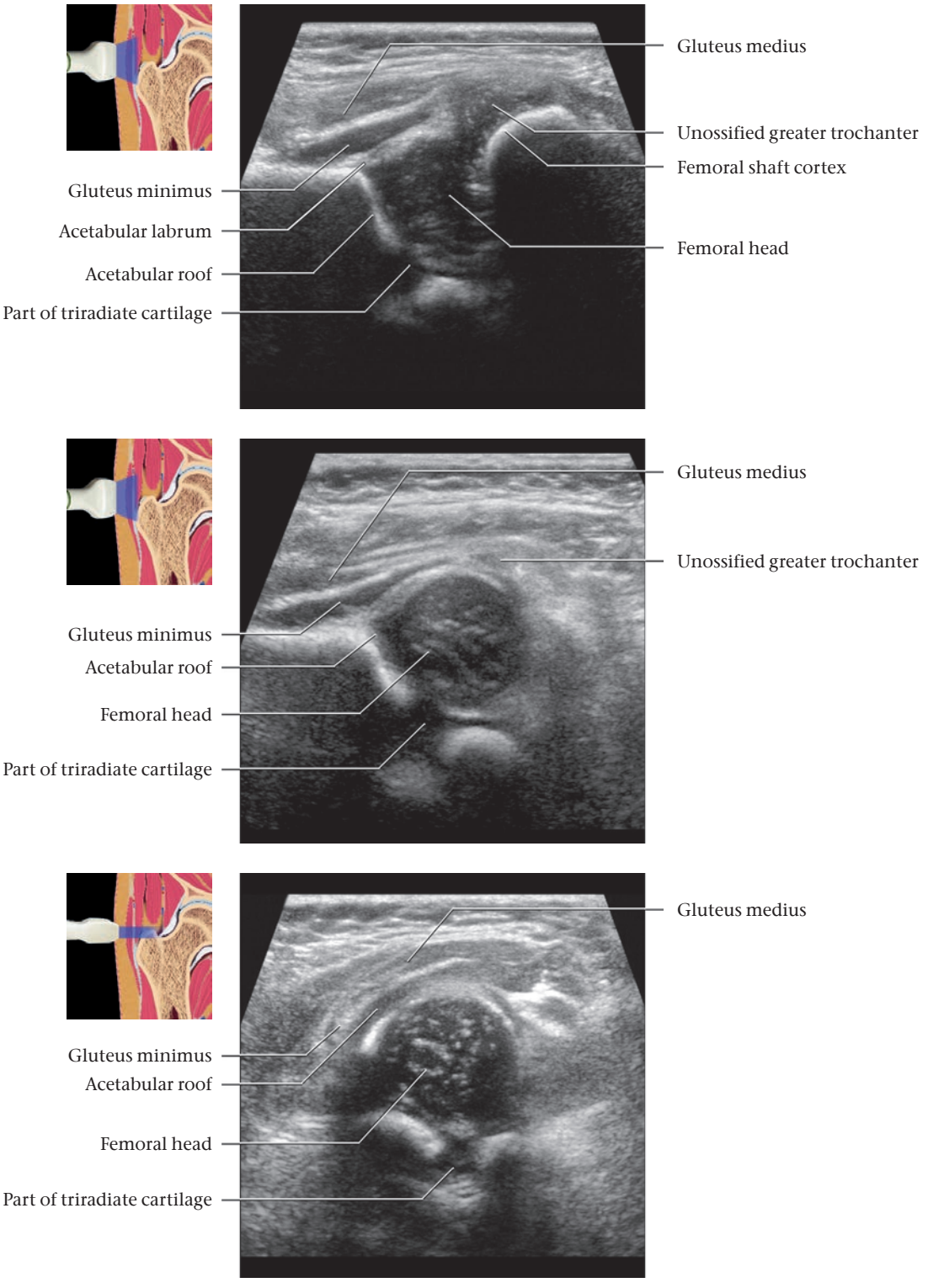
GREATER TROCHANTER



(Top) *Coronal panoramic scan shows the greater trochanter. The gluteus minimus & medius tendons insert on the anterior, lateral, and superoposterior facets of the greater tuberosity. The iliotibial tract originates from the anterior aspect of the iliac crest (as the tensor fascia lata muscle) and runs inferiorly, passing superficial to the lateral surface of the greater trochanter.* ***(Middle)*** *Transverse scan through the anterior facet of the greater trochanter shows insertion of the gluteus minimus tendon. The gluteus medius tendon & iliotibial tract pass superficial to this.* ***(Bottom)*** *Transverse scan of the lateral facet of the greater trochanter shows the insertion of the gluteus medius tendon. The iliotibial tract is closest to the trochanter at this point and may be irritated, resulting in the formation of bursitis (trochanteric bursitis).*

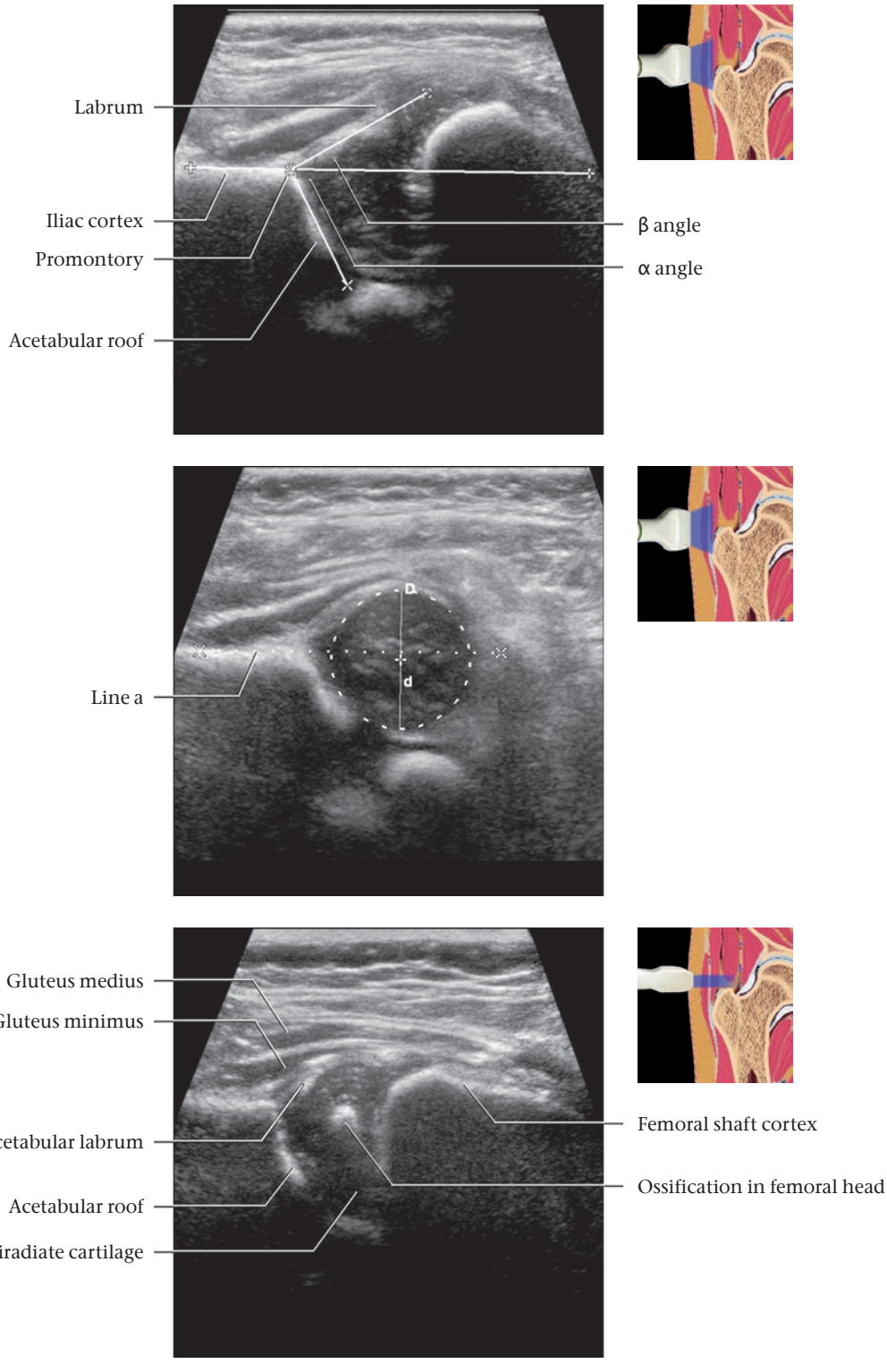
HIP

PEDIATRIC HIP



(Top) *Coronal scan shows the hip of a 1-month-old neonate with the hip in extension. The femoral head and the greater trochanter are purely cartilaginous. This allows ultrasound transmission and thus visualization of the acetabular fossa.* ***(Middle)*** *Coronal scan shows the hip of a 1-month-old neonate with the hip in flexion, which produces an axial section of the femoral head. The femoral head should appear round in this section. Both the femoral head and the greater trochanter are purely cartilaginous, allowing ultrasound transmission and thus better visualization of the depth of the acetabular fossa.* ***(Bottom)*** *Transverse scan of the femoral head with hip in extension also shows the central position of a normal femoral head on the triradiate cartilage ("golf ball on tee" appearance).*

PEDIATRIC HIP



(Top) *Three lines are drawn on the standard coronal image of the pediatric hip: (A) along straight contour of iliac cortex, (B) from promontory along acetabular roof to describe the* α *angle, and (C) from promontory to tip of labrum for* β *angle. Normal ranges are* α *angle > 60˚ and* β *angle < 55˚. Measurements outside of these ranges are suggestive of developmental hip dysplasia.* ***(Middle)*** *The proportion of the femoral head contained within the acetabulum is calculated by dividing the depth (d) of femoral head below line a by the diameter of the femoral head (D). In normal subjects, > 50% of the femoral head should be below line a.* ***(Bottom)*** *Coronal scan shows the hip of a 4-month-old child with the hip in extension. The center of the femoral head has begun to ossify, showing up as an echogenic focus with posterior acoustic shadowing.*

THIGH MUSCLES

TERMINOLOGY

Abbreviations

- Anterior superior iliac spine (ASIS), artery (a.), function (F), insertion (I), ligament (l.), muscle (m.), nerve (n.), origin (O), vein (v.), tendon (t.)

IMAGING ANATOMY

Compartment Anatomy

- **Compartmental anatomy is different from functional groupings**
- Thigh divided into anterior, medial, and posterior compartments
  - **Anterior compartment**: Iliotibial tract, tensor fascia lata muscle, quadriceps muscles, sartorius muscle
  - **Medial compartment**: Gracilis muscle, adductor muscles
  - **Posterior compartment**: Hamstring muscles, short head of biceps femoris muscle, sciatic nerve
- Additional muscles at junction pelvis/thigh
  - Pectineus, iliopsoas, obturator externus, lateral femoral muscles
- Extensions from fascia lata divide compartments
  - Medial intermuscular septum: Anterior/medial
  - Lateral intermuscular septum: Anterior/lateral
  - Thin fascia separates medial, posterior compartments
- Clinical note: Compartment anatomy critical to tumor staging and biopsy planning
  - Cross compartment extension of tumor, contamination by biopsy requires change from limb salvage to amputation

Medial Femoral Muscles

- Anterior division: Adductor brevis and longus, gracilis muscles
- Posterior division: Adductor portion adductor magnus muscle
- Common function: Hip adduction; assist hip flexion, internal rotation (except obturator externus muscle)
- **Adductor brevis**
  - O: Inferior pubic ramus
  - I: Inferior 2/3 pectineal line, superior 1/2 medial lip of linea aspera
- **Adductor longus**
  - O: Pubic body inferior to crest
  - I: Medial lip of linea aspera
- **Adductor magnus**: 2 separate muscles with different innervations and functions
  - Adductor portion
    - O: Ischiopubic ramus
    - I: Gluteal tuberosity, medial lip linea aspera, medial supracondylar line
  - Adductor hiatus between 2 divisions of muscle in distal thigh
- **Gracilis**
  - O: Inferior pubic ramus, symphysis pubis
  - I: Medial proximal tibia (pes anserine)
  - F: Also assists knee flexion
- **Obturator externus**
  - O: External margins of obturator foramen membrane
  - I: Piriformis fossa
  - F: Hip external rotation only
- **Pectineus**
  - O: Superior pubic ramus, pecten
  - I: Pectineal line femur
  - Femoral nerve ± accessory obturator nerve
  - Unclear pre- or postaxial muscle

Anterior Femoral Muscles

- Common function: Knee extension (except sartorius muscle)
- **Rectus femoris**
  - O: Straight head = anterior inferior iliac spine; reflected head = groove above acetabulum
  - I: Superior patella, tibial tuberosity
  - F: Also hip flexion
  - Crosses 2 joints
- **Sartorius**: (Tailor's muscle)
  - O: ASIS, notch below
  - I: Proximal medial tibia (pes anserine)
  - F: Hip flexion, abduction, external rotation; knee flexion
  - Crosses 2 joints
  - Longest muscle in body
  - Separate fascial covering
- **Vastus lateralis**
  - O: Superior intertrochanteric line femur, anterior and inferior greater trochanter, gluteal tuberosity, lateral lip of linea aspera, lateral intermuscular septum
  - I: Lateral tibial condyle (lateral patellar retinaculum) superolateral patella (quadriceps tendon)
  - Largest quadriceps muscle
- **Vastus medialis**
  - O: Entire medial lip of linea aspera, inferior intertrochanteric line, medial intermuscular septum
  - I: Tendon of rectus femoris muscle, superomedial patella (quadriceps tendon), medial condyle tibia (medial patellar retinaculum)
- **Vastus intermedius**
  - O: Anterior and lateral femoral shaft, inferior lateral lip of linea aspera, lateral intermuscular septum
  - I: Blends along deep aspect rectus femoris, vastus medialis, vastus lateralis muscles
- **Quadriceps femoris**: Rectus femoris, vastus lateralis, vastus medialis, vastus intermedius muscles
  - Common tendon of insertion onto superior, lateral, medial patella

Posterior Femoral Muscles

- Common functions: Hip extension, knee flexion
- **Biceps femoris**
  - Long head: O: Ischial tuberosity (inferior, medial)
    - Common tendon with semitendinosus muscle
  - Short head: O: Lateral lip of linea aspera femur, lateral supracondylar line, lateral intermuscular septum
    - Postaxial muscle
    - Not part of hamstring muscles
  - I: Fibular head, lateral condyle tibia
  - F: Also external rotation flexed knee
- **Semimembranosus**
  - O: Ischial tuberosity (superior, lateral)
  - I: Posterior medial condyle tibia, popliteal fascia
    - Some fibers extend to form oblique popliteal ligament
  - F: Also internal rotation flexed knee
  - Membranous in upper thigh
- **Semitendinosus**
  - O: Ischial tuberosity (inferior, medial)

- Common tendon of long head biceps femoris muscle
- I: Medial proximal tibia (pes anserine)
- F: Internal rotation flexed knee
- Entirely tendinous in distal thigh

· **Ischiocondylar portion of adductor magnus**
- O: Ischial tuberosity
- I: Adductor tubercle
- Medial-most aspect adductor magnus muscle

· **Hamstrings**: Long head biceps femoris, semimembranous, semitendinosus, ischiocondylar portion adductor magnus muscles
- Does not include short head biceps femoris muscle

· **Pes anserine**
- Common aponeurosis for insertion gracilis, semitendinosus, sartorius tendons
- Pes anserine bursa between tendons and tibia

Lateral Femoral (Gluteal) Muscles

· **Iliotibial tract/band**: Lateral thickening fascia lata
- O: Tubercle iliac crest
- I: Lateral condyle tibia
- Insertion site tensor fascia lata muscle, portion of gluteus maximus muscle

Hip Flexors

· **Iliopsoas**: I: Lesser trochanter
- Iliacus
  - O: Iliac crest, iliac fossa, sacral ala, sacroiliac joint capsule
  - Femoral nerve
- Psoas major
  - O: Lateral vertebral body and intervertebral discs T12-L5, all lumbar transverse processes
  - L1, L2, L3
- Psoas minor
  - O: Lateral vertebral body T12, L1 and T12-L1 intervertebral disc
  - L1, L2

· Sartorius and pectineus

Femoral Triangle

· Anterior wall: Inguinal ligament
· Posterior wall: Adductor longus and pectineus muscles (medial), iliopsoas muscle (lateral)
· Medial border: Adductor longus muscle
· Lateral border: Sartorius muscle
· Apex: Crossing of adductor longus and sartorius muscles
· Contents: Femoral nerve and branches, femoral vessels, lymph node (Cloquet node), femoral sheath
- Structures lateral to medial at entrance: NAVeL
  - Nerve, artery, vein, lymphatics

· Femoral artery/vein relationships
- Entrance: Artery lateral
- Apex: Artery anterior

· Femoral nerve branches within triangle
- Saphenous nerve and nerve to vastus medialis are only branches to exit triangle

· **Femoral sheath**: Transversalis fascia covers vessels proximally
- 3 compartments
  - Lateral: Artery
  - Middle: Vein
  - Medial: Lymph node (femoral canal)

· **Femoral canal**: Medial compartment femoral sheath
- Anterior border: Inguinal ligament
- Posterior border: Pubic bone
- Medial border: Lacunar ligament
- Lateral border: Femoral vein
- Entrance: **Femoral ring**
  - Anterior border: Medial inguinal ligament
  - Posterior border: Superior pubic ramus
  - Medial border: Lacunar ligament
  - Lateral border: Septum between femoral canal and femoral vein
  - Open to peritoneal cavity
- Contents: Lymphatic vessels and nodes (**Cloquet node**), fat, connective tissue
  - Groin lymph nodes divided into superficial and deep groups
  - Superficial nodes are situated around superficial veins
  - Deep nodes lie medial to femoral vein
  - Node of Cloquet in most medial of deep group; located medial to femoral vein at femoral triangle
- Clinical note: **Femoral hernia**
  - Lateral and inferior to pubic tubercle
  - Travels femoral ring to femoral canal to saphenous opening to subcutaneous tissue

Adductor (Subsartorial or Hunter) Canal

· Fascial passageway for vessels midthigh
- Boundaries are fascial surfaces of adjacent muscles

· Anteromedial border: Sartorius muscle
· Anterolateral border: Vastus medialis muscle
· Posterior border: Adductor longus and magnus muscles
· Entrance: Apex femoral triangle
· Exit: Adductor hiatus
- **Adductor hiatus**: Gap adductor magnus muscle between adductor portion and ischiocondylar portion of distal thigh

· Vessel passageway from thigh to popliteal fossa
· Contents: Femoral artery and vein, saphenous nerve
- Nerve initially anterior to artery then medial
- Artery anterior to vein
- Descending geniculate artery arises in canal

ANATOMY IMAGING ISSUES

Imaging Recommendations

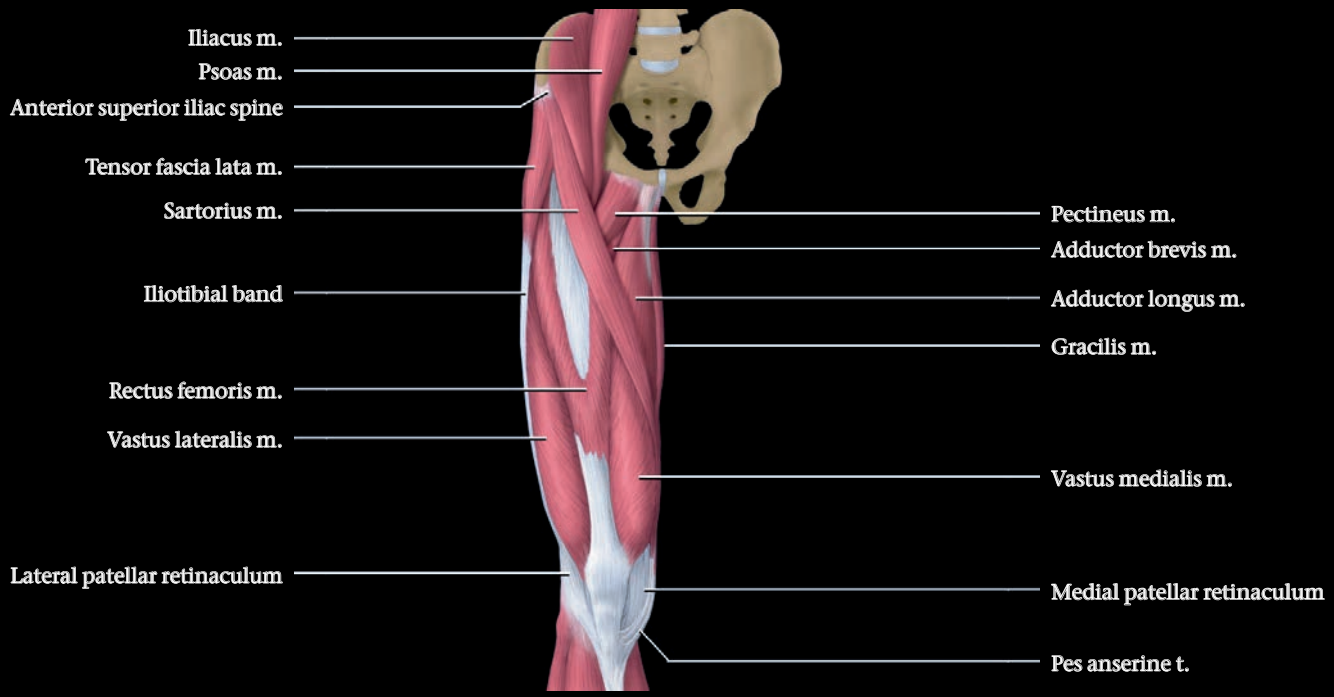
· US
- Highest combined spatial and contrast resolution of the different imaging modalities
  - Important for detecting and characterizing small lesions or fine anatomy, e.g., small nerve sheath tumors, internal vascularity of lesions, etc.
- Real-time interrogation allows evaluation of muscle and tendon movement during dynamic maneuvers, e.g., for snapping hips, nerve impingement, etc.
- Limited by depth of penetration

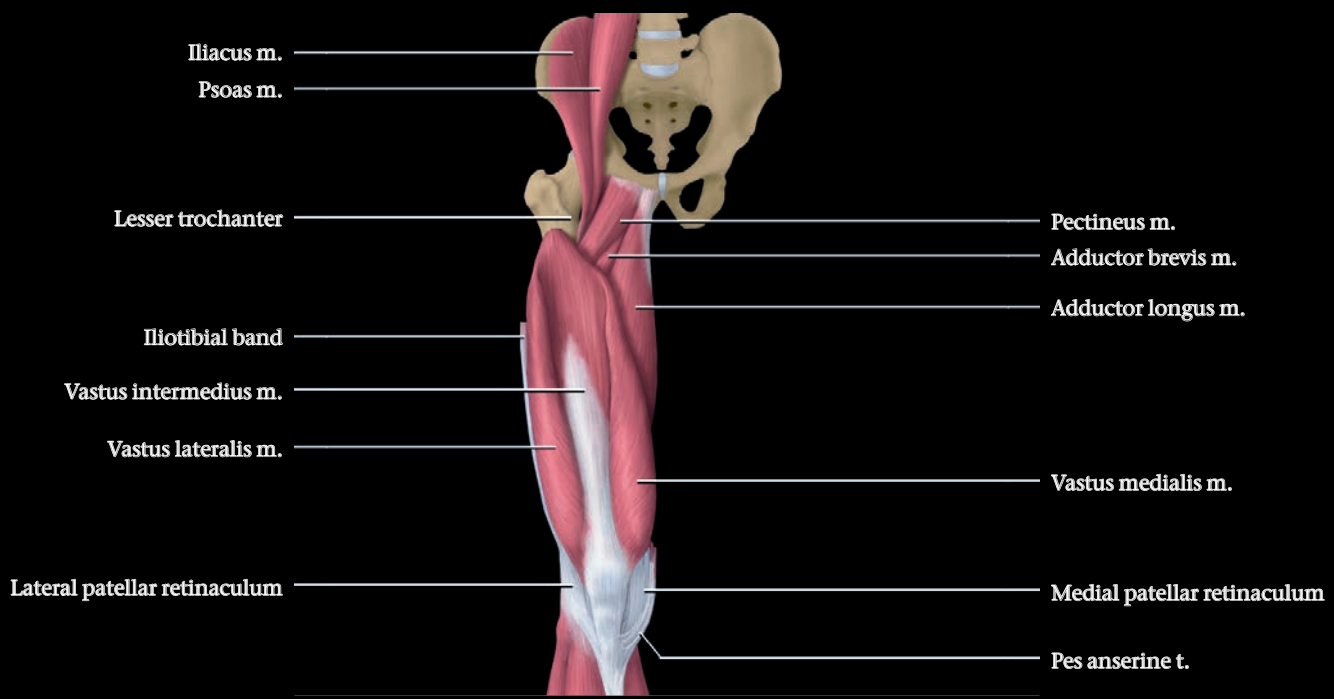
· CT
- Best for evaluating osseous integrity
- Soft tissue assessment inferior to US and MR

· MR
- Highest contrast resolution especially when using fluid-sensitive or contrast-enhanced sequences
- Most sensitive modality to detect tissue edema

THIGH MUSCLES

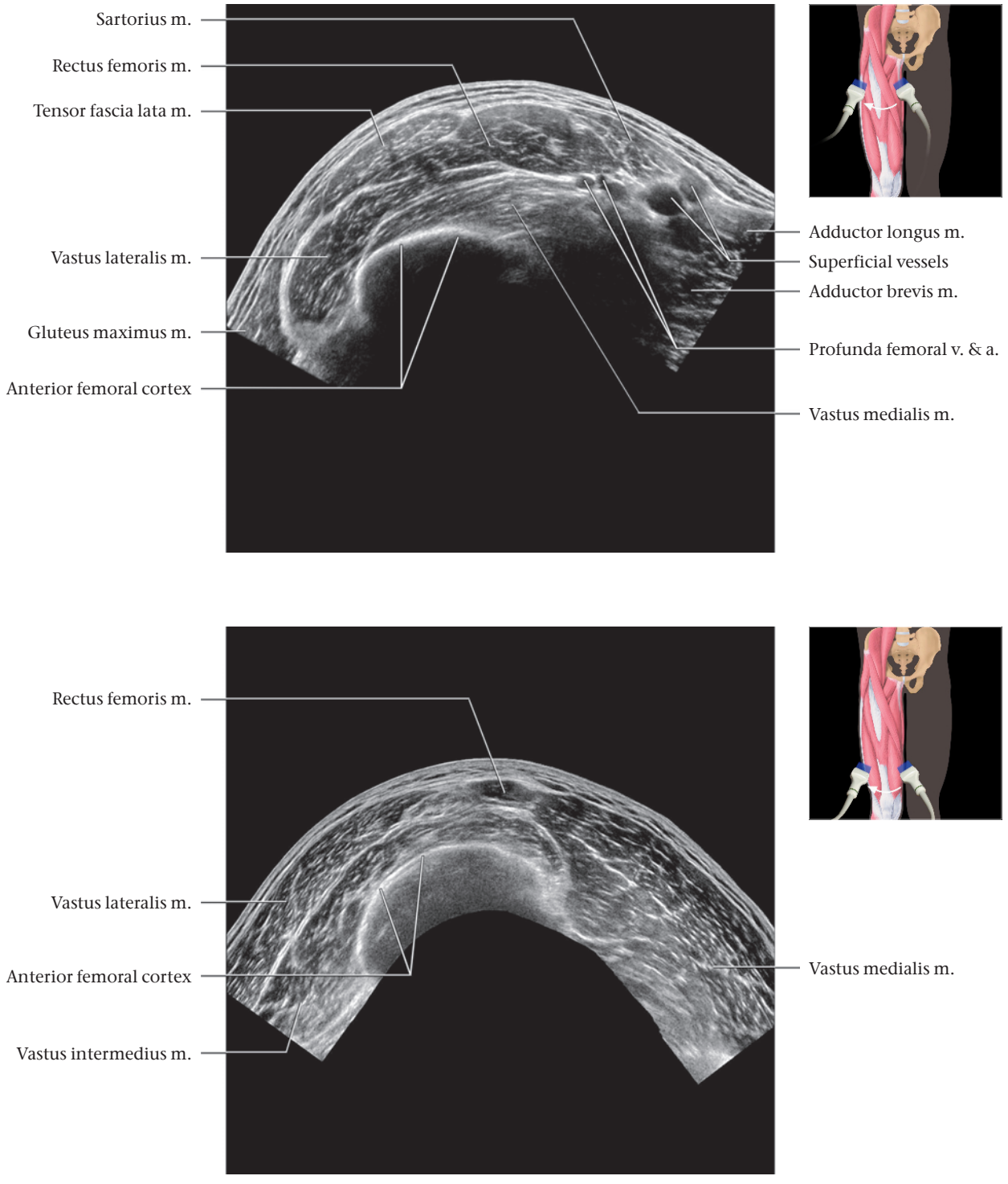
GRAPHICS, ANTERIOR THIGH





(Top) *Superficial muscles of the anterior thigh are shown. The oblique course of the sartorius muscle is easily appreciated. The adductor brevis muscle is deep to the adductor longus and pectineus muscles. The most medial muscle is the gracilis. The vastus lateralis and medialis muscles continue to their insertions as the lateral and medial patellar retinacula, respectively.* ***(Bottom)*** *Deep muscles of the anterior thigh are shown. The vastus intermedius muscle is deep to the rectus femoris muscle. The vastus intermedius muscle tendon blends with the rectus femoris tendon along its deep surface. The iliopsoas muscle dives deep after crossing over the pelvic brim. With removal of the sartorius muscle, a little more of the adductor brevis muscle is visible. The pes anserine tendons, the gracilis, sartorius, and semitendinosus have a conjoined insertion into the proximal medial tibia.*

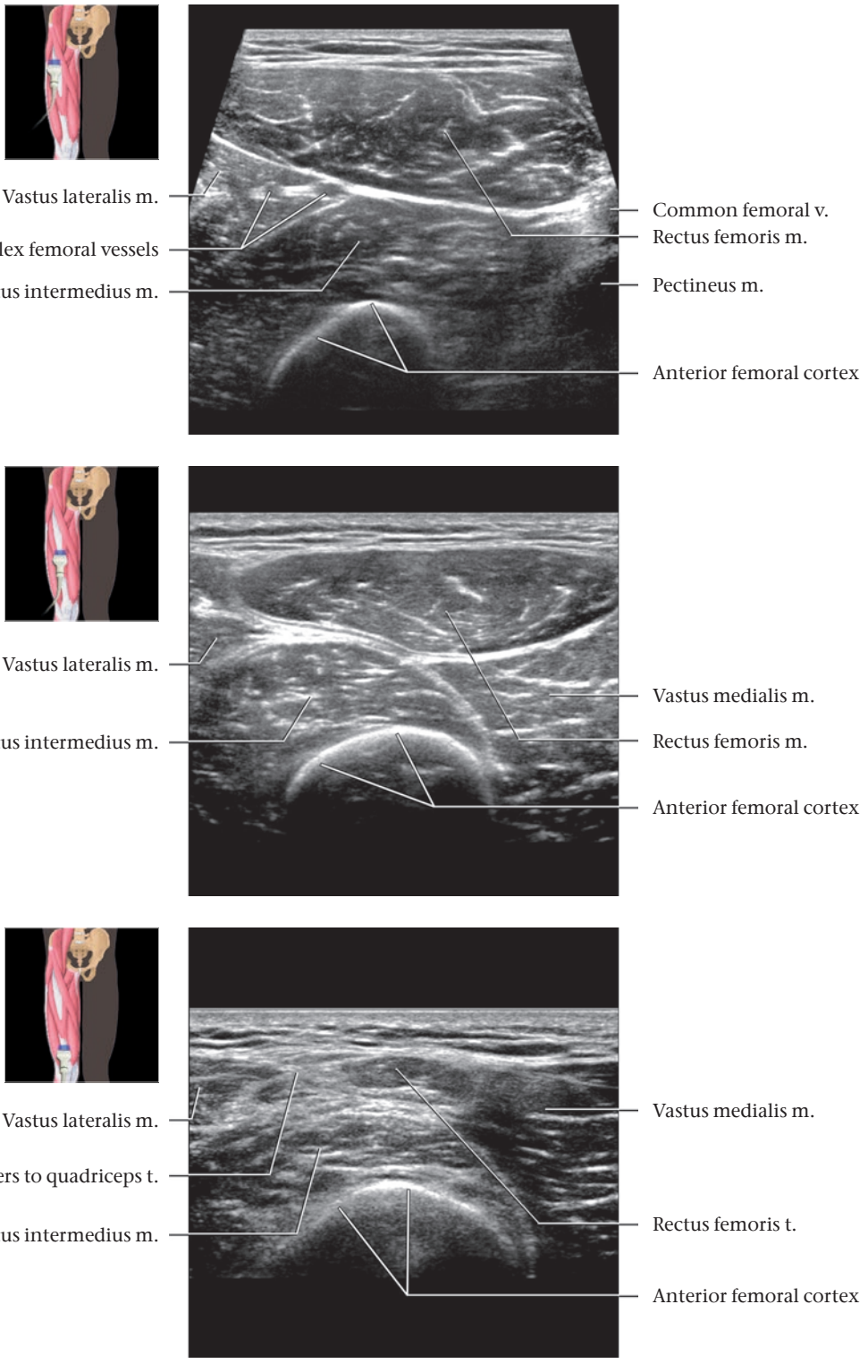
OVERVIEW, ANTERIOR THIGH



(Top) *Transverse panoramic view shows the anterior compartment of the upper thigh. The anterior compartment is composed of the quadriceps muscle, tensor fascia lata/iliotibial tract, and sartorius muscle. Medially, it is bordered by the femoral neurovascular bundle and adductor muscles. Laterally, it is bordered by the gluteal and hamstring muscles.* ***(Bottom)*** *In the lower thigh, the rectus femoris is much reduced in size and will continue inferiorly as the quadriceps tendon. The rest of the quadriceps continue as bulky muscles down to the suprapatellar level. They contribute directly to the quadriceps femoris tendon. The major neurovascular bundle has moved to the posterior compartment, and the only anterior compartment vessels are branches of the profunda femoris artery and vein.*

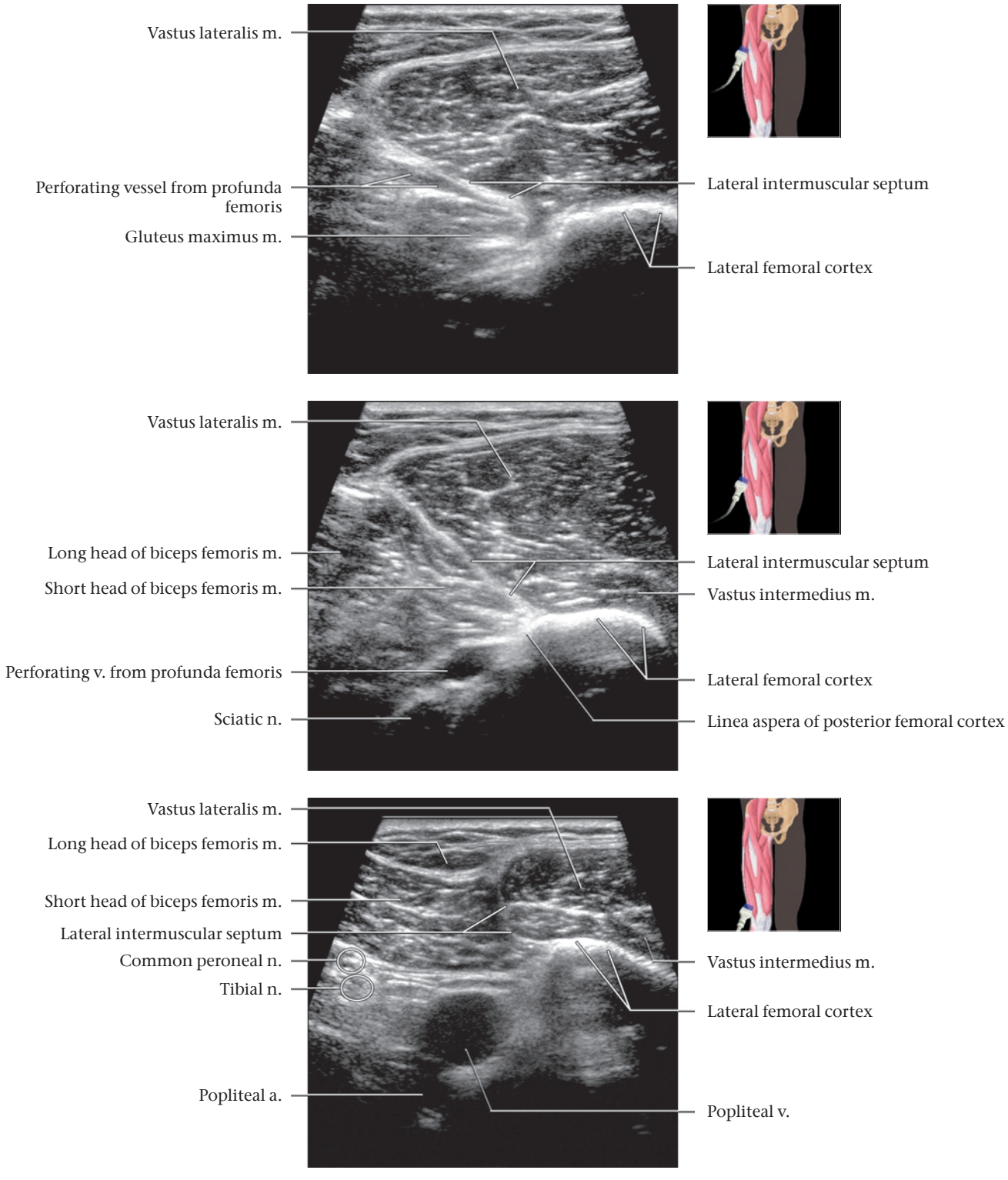
THIGH MUSCLES

ANTERIOR COMPARTMENT, CENTRAL



(Top) *Series of 3 transverse scans shows the central part of the anterior compartment. At the proximal level, the dominant (in terms of bulk) quadriceps muscle is the rectus femoris muscle. It is easily identified by its central position; it is lateral to the femoral neurovascular bundle (the femoral triangle). The lateral circumflex artery is important because together with the medial circumflex, its posterior counterpart, they supply the head of the femur.* ***(Middle)*** *Transverse scan is shown through the midthigh. The vastus medialis and intermedius have originated, and at this level, all 4 quadriceps muscles can be seen.* ***(Bottom)*** *Transverse scan shows the distal thigh, above the level of the suprapatellar pouch. The rectus femoris has become a central tendon, which receives contributions from the vasti muscles.*

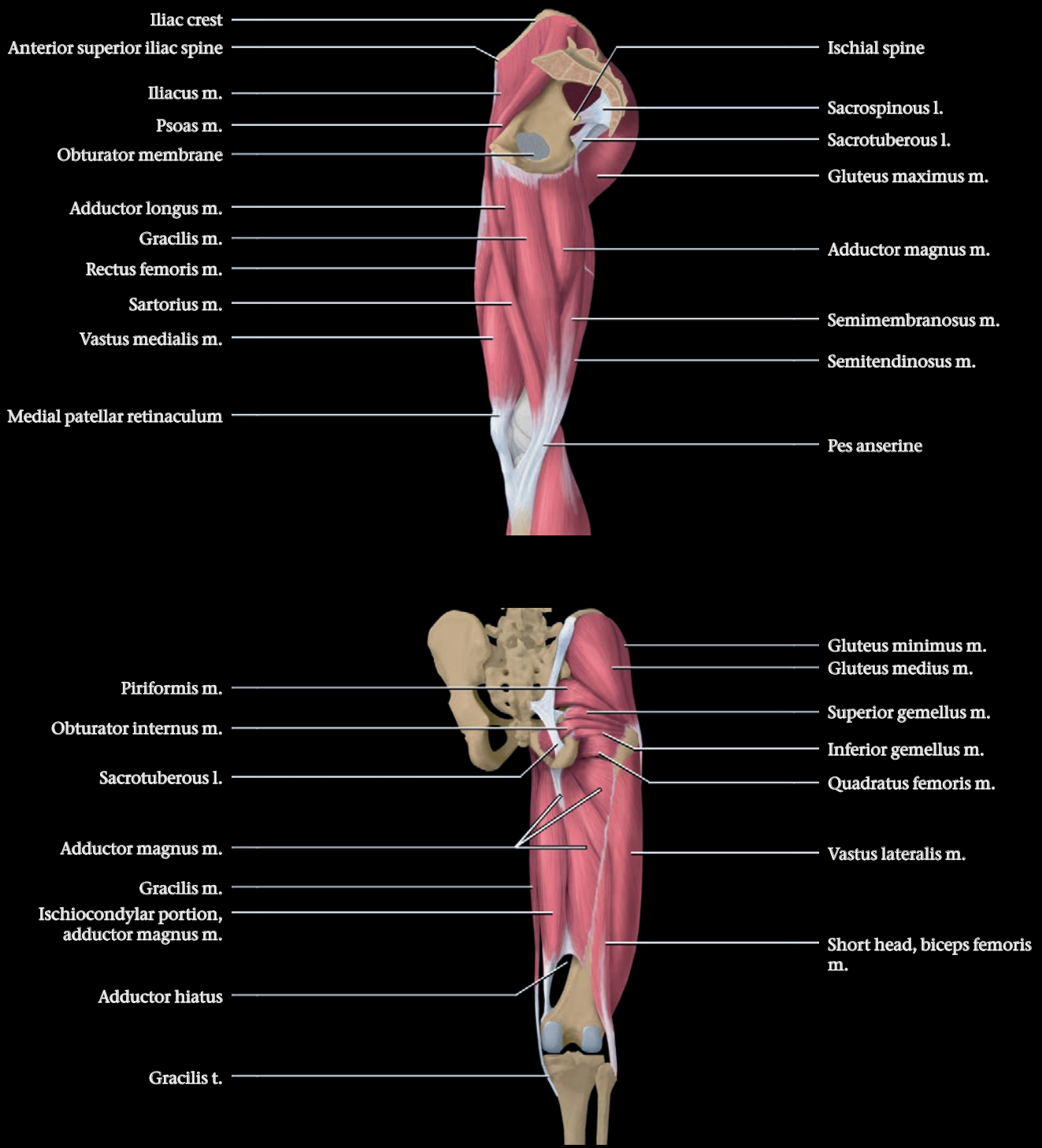
ANTERIOR COMPARTMENT, LATERAL



(Top) *Series of transverse scans through the lateral aspect of the thigh is shown. Proximally, the vastus lateralis muscle is dominant & borders with the gluteus maximus muscle (which inserts onto the posterior surface of the femur). The lateral intermuscular septum separates anterior from posterior compartments laterally and also acts as conduit for vessels.* ***(Middle)*** *Further inferiorly, the vastus lateralis borders the biceps femoris. The linea aspera is a distinct protrusion from the posterior femoral shaft where many muscles originate and insert, including the lateral intermuscular septum. On ultrasound, it is consistently seen and therefore serves as a useful bony landmark.* ***(Bottom)*** *At the superior popliteal level, the vastus lateralis muscle becomes less bulky (the reverse occurs with the vastus intermedius muscle), as does the bordering long head of the biceps muscle. The sciatic nerve divides into tibial and common peroneal branches.*

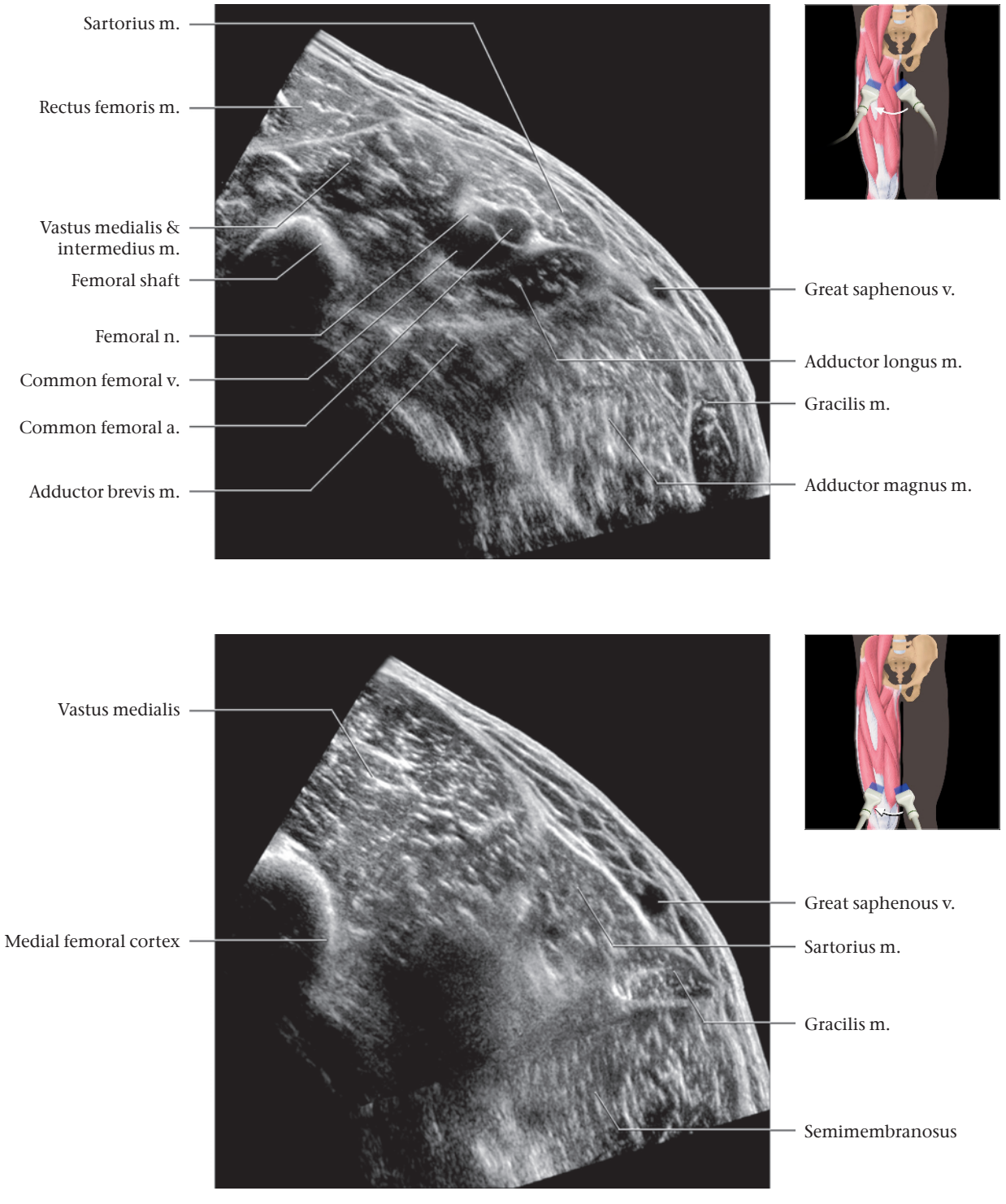
THIGH MUSCLES

GRAPHICS, MEDIAL AND POSTERIOR THIGH



(Top) *Medial muscles of the thigh are shown. The gracilis muscle has a thin profile when viewed from the front; however, when viewed from the side, it is quite broad. The semimembranosus muscle runs along the deep surface of the semitendinous muscle and inserts onto the tibia posterior to the pes anserine tendons. Its insertion is hidden on this image. The iliopsoas muscle courses over the pelvic brim on its course to the lesser trochanter.* ***(Bottom)*** *Deep muscles of the posterior thigh are shown. With removal of the hamstring muscles, the expansive adductor magnus muscle is visible. The separation of its 2 heads in the distal thigh forms the adductor hiatus.*

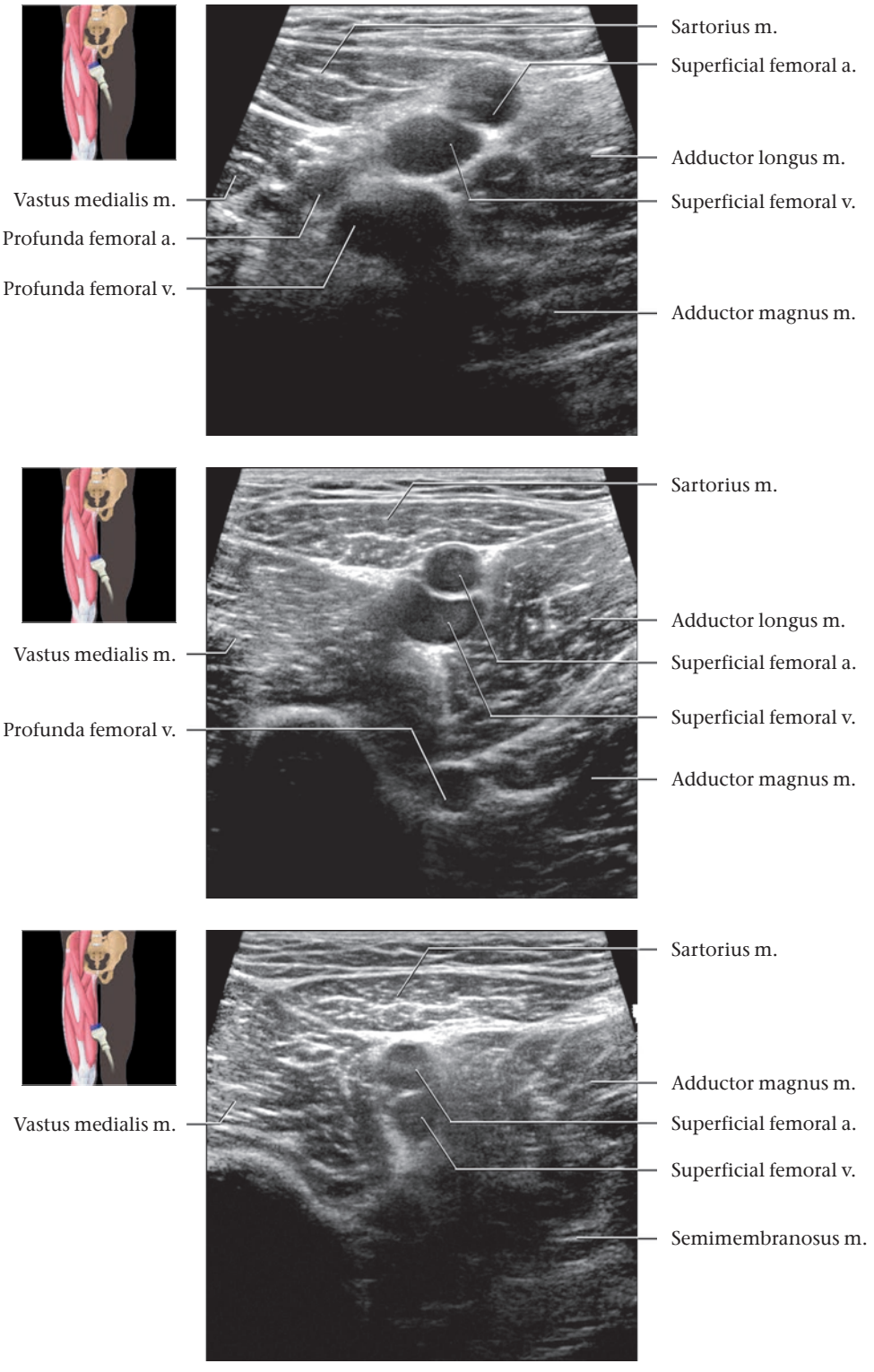
OVERVIEW, MEDIAL THIGH



(Top) *Transverse panoramic view shows the medial compartment at the upper thigh level. At this level, all 3 adductor muscles can be seen, together with the gracilis muscle. This compartment is bordered anteriorly by the femoral triangle, which continues inferiorly as the adductor canal. Posteriorly, the medial compartment is bordered by the semimembranosus muscle.* ***(Bottom)*** *Transverse panoramic scan shows the medial aspect of the lower thigh. At this level, the adductor muscles have inserted superiorly; therefore, the medial compartment is much smaller and composed mainly of the gracilis muscle. The adductor hiatus, which is above this level, provides an entrance for the femoral vessels into the popliteal fossa.*

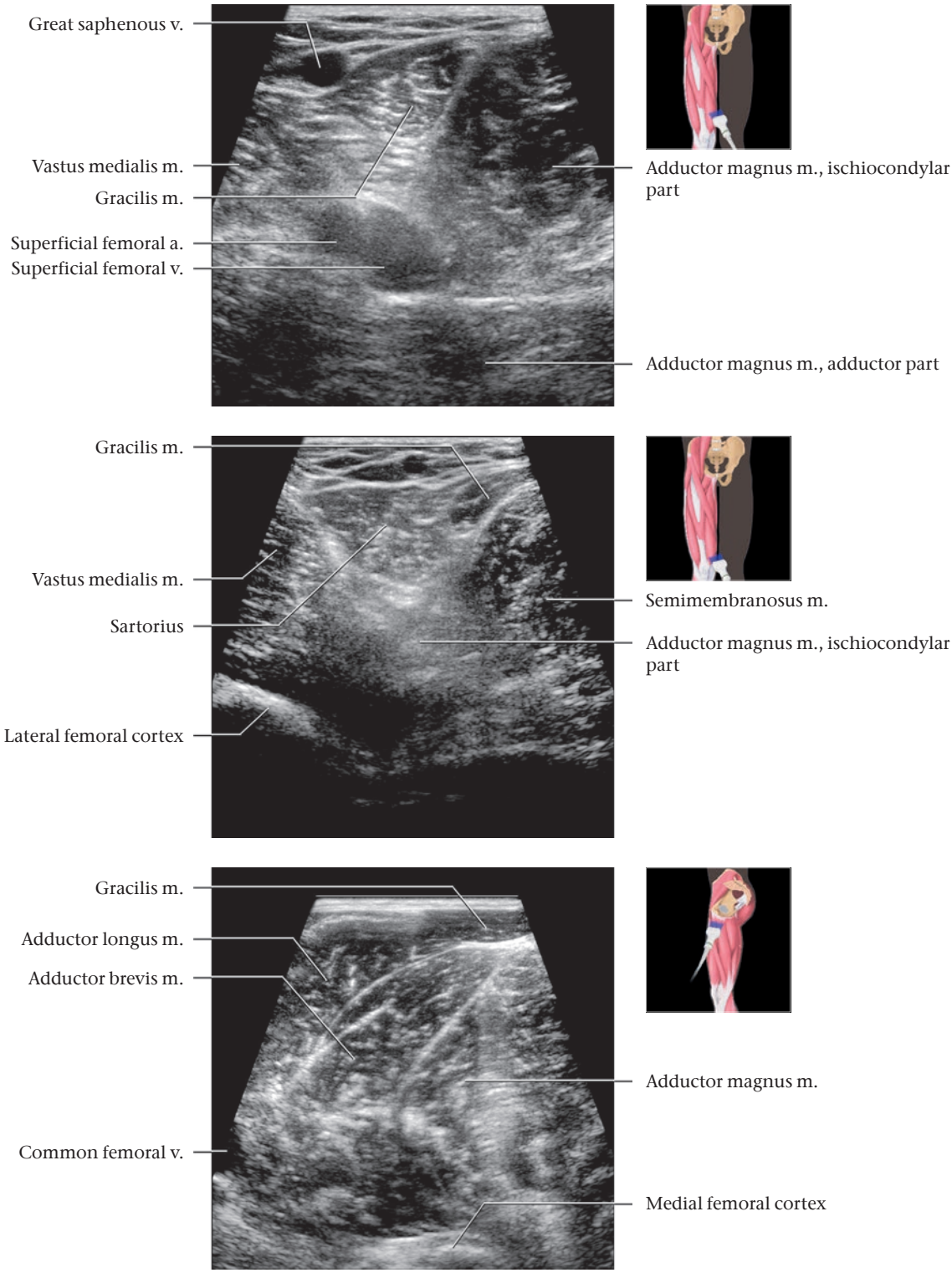
THIGH MUSCLES

MEDIAL THIGH, ADDUCTOR CANAL



(Top) *Transverse scan shows the anterior part of the medial thigh. Above the adductor canal, the apex of the femoral triangle contains bifurcation of the common femoral vessels. The profunda will run deep to supply the thigh muscles and femur. The superficial femoral vessels continue into the adductor canal.* ***(Middle)*** *Transverse scan more inferiorly shows that the superficial femoral vessels are now under the cover of the sartorius muscle, indicating that they are in the adductor canal.* ***(Bottom)*** *Transverse scan shows the medial aspect of the midthigh. The common adductor canal continues medially and more deeply. At this level, the medial wall of the adductor canal changes from the adductor longus muscle to the adductor part of the adductor magnus muscle.*

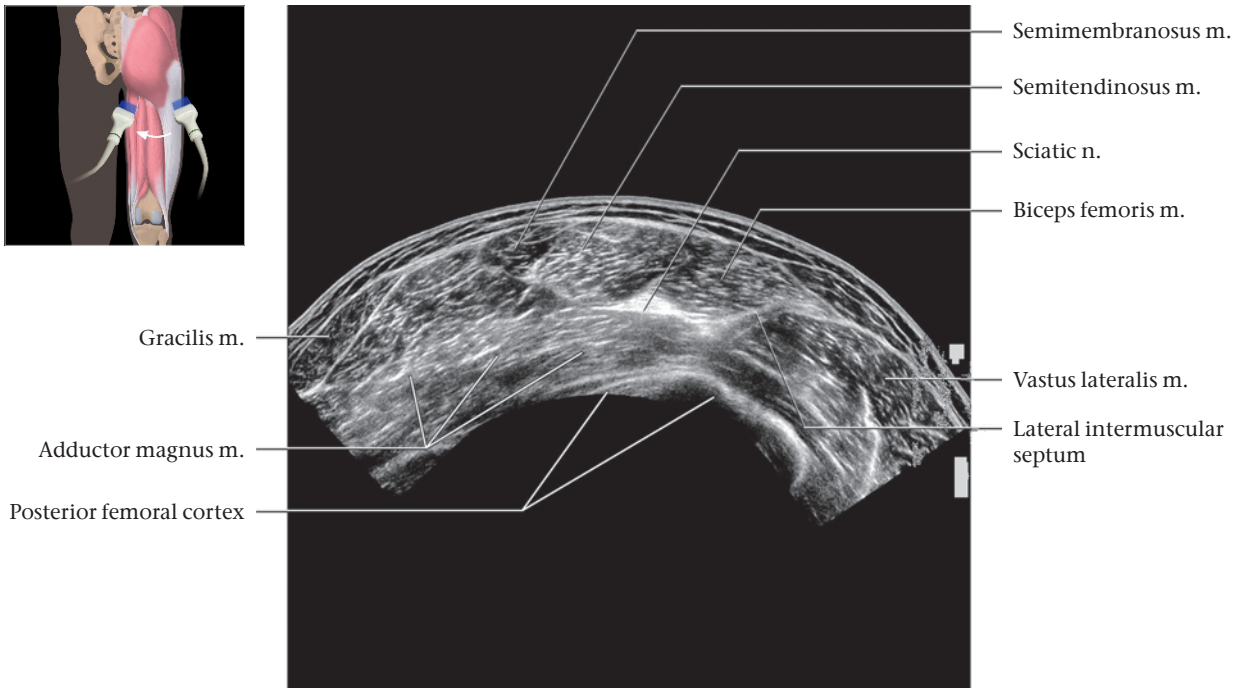
MEDIAL THIGH

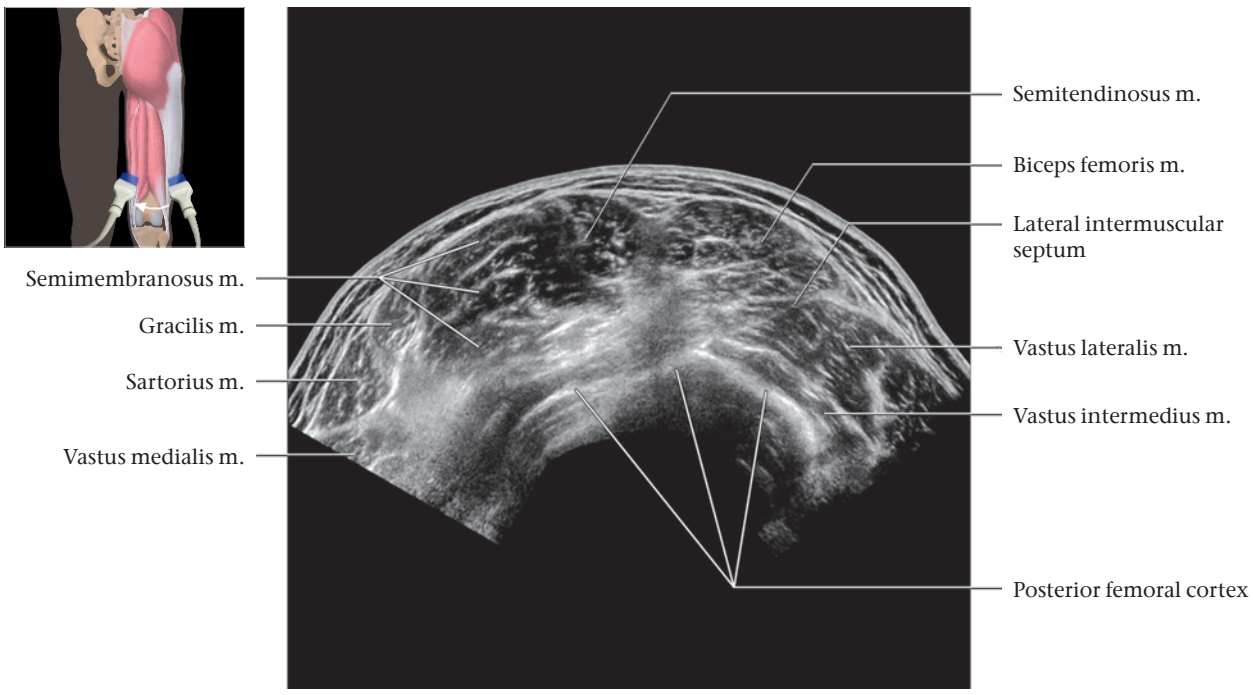


(Top) *Transverse scan using an anteromedial approach is shown. At this level, the superficial femoral vessels enter the popliteal fossa via the adductor hiatus, which is a gap in the adductor magnus muscle, between the adductor and ischiocondylar parts before their insertions (on the medial supracondylar line and adductor tubercle, respectively).* ***(Middle)*** *More inferiorly, only the gracilis muscle and the ischiocondylar part of the adductor magnus (acting like a hamstring) are left in the the medial compartment. This space is encroached on by the vastus medialis muscle anteriorly and semimembranosus muscle posteriorly.* ***(Bottom)*** *Using a medial approach (from the inner thigh), the deeper muscles can be demonstrated. The adductor longus and brevis muscle plus the gracilis muscle form an anterior division, while the bulky adductor magnus muscle forms the posterior division.*

THIGH MUSCLES

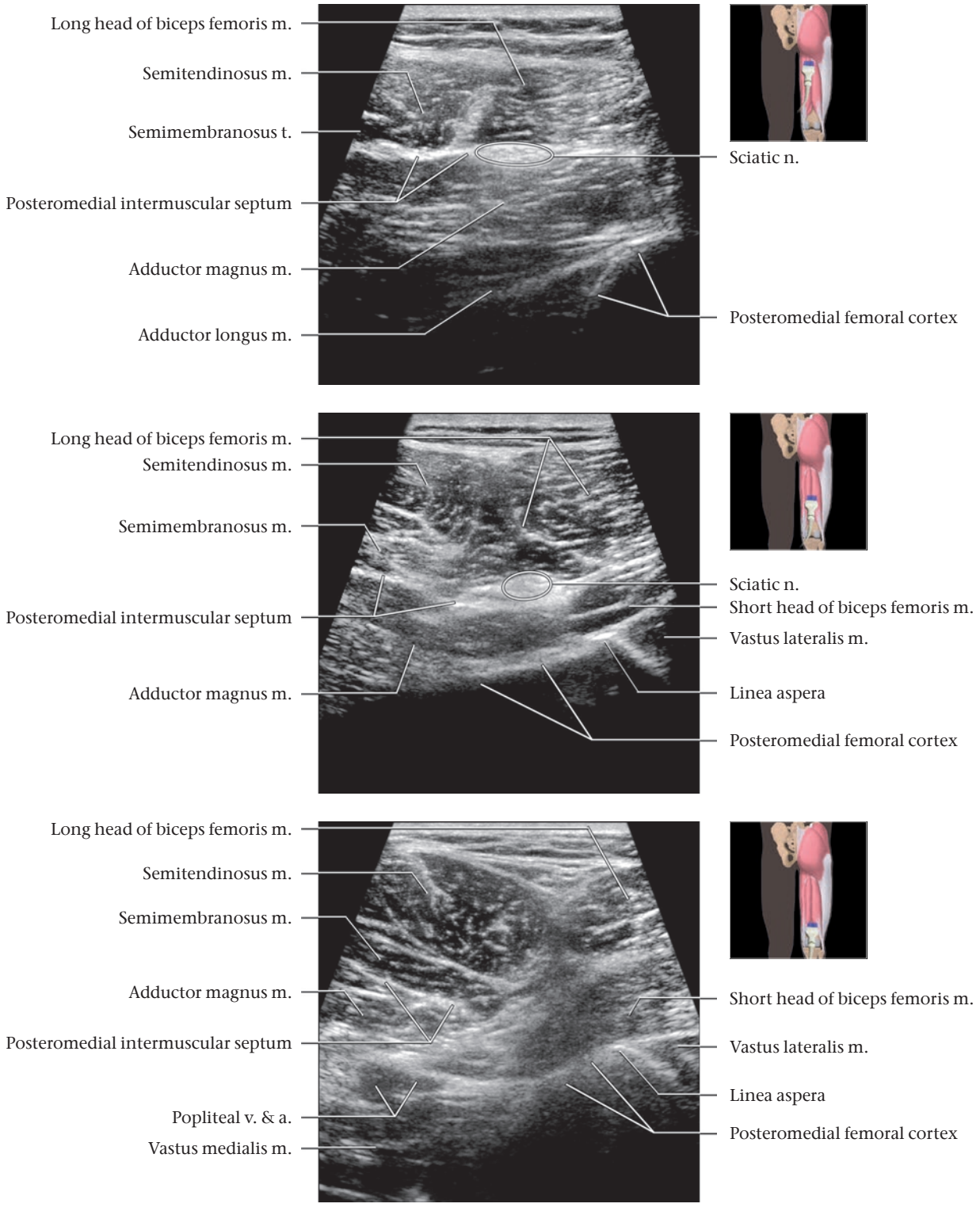
OVERVIEW, POSTERIOR





(Top) *Transverse panoramic scan shows the posterior compartment at the upper-thigh level. At this level, the hamstring muscles form a small proportion of the posterior muscle bulk. The main contributions come from adductors (the medial compartment) and vastus lateralis (the anterior compartment). The sciatic nerve runs under the cover of the biceps femoris muscle.* ***(Bottom)*** *Transverse panoramic scan shows the posterior aspect of the distal thigh. At this more inferior level, the hamstrings form a much larger proportion of the posterior muscle bulk. In particular, the semimembranosus becomes the dominant muscle on the posteromedial side, as most of the adductors have inserted onto the femur above this level.*

POSTERIOR THIGH



(Top) *Series of 3 transverse scans show the central portion of the posterior thigh. After their origin from the ischial tuberosity, the semitendinosus and semimembranosus muscles run on the medial side and the biceps femoris muscle runs on the lateral side. The sciatic nerve is under the cover of the biceps femoris for most of its way to the popliteal fossa.* ***(Middle)*** *At the midthigh level, the hamstrings are bulkier and the adductors smaller. The 2 groups are divided by the posteromedial intermuscular septum.* ***(Bottom)*** *Further inferiorly, the popliteal vessels enter via the adductor hiatus into the popliteal fossa. The superior aspect of the popliteal fossa is lined by the semimembranosus and semitendinosus muscle medially and the biceps femoris laterally.*

FEMORAL VESSELS AND NERVES

TERMINOLOGY

Abbreviations

- Artery (a.)
- Ligament (l.)
- Muscle (m.)
- Nerve (n.)
- Vein (v.)

IMAGING ANATOMY

Femoral Vessels

- Enter thigh deep to inguinal ligament, midpoint between anterior superior iliac spine (ASIS) and symphysis pubis
  - Change from external iliac vessels to common femoral vessels
- Upper thigh: Vessels within femoral triangle
  - Enter: Artery lateral to vein
  - Exit: Artery anterior
- Midthigh: Vessels within adductor canal
  - Enter: Artery anterior to vein
  - Exit: Artery anterior
- Distal thigh: Exit adductor canal via adductor hiatus, enter popliteal fossa
- **Common femoral artery branches**
  - **Superficial epigastric**, **superficial circumflex iliac**, **superficial external pudendal** arise anteriorly
  - **Deep external pudendal** arises medially
    - May branch from medial circumflex femoral
  - Divides into superficial and deep branches
  - **Superficial femoral artery**
    - Branch: **Descending genicular**
  - **Deep femoral (profunda femoris)**
    - Arises laterally in femoral triangle
    - Dives between pectineus and adductor longus muscles
    - Medial to femur, deep to adductor longus muscle
    - Branches in femoral triangle: **Medial circumflex femoral** (main supply femoral head and neck), lateral circumflex femoral, muscular branches
    - Branches in adductor canal: 3 perforating branches, descending genicular
    - Terminal branch: 4th perforating artery
- **Femoral vein:** Travels with artery
  - Tributaries: Lateral circumflex femoral vein, deep femoral vein and its associated perforating veins, descending genicular, lateral circumflex femoral, medial circumflex femoral, deep external pudendal, greater saphenous veins
  - **Greater saphenous vein**
    - Longest vein in body
    - Toes to saphenous opening (fascia lata)
    - Tributaries: Accessory saphenous, superficial epigastric, superficial circumflex femoral, superficial external pudendal veins

Femoral Nerve

- Nerve contributions from L2, L3, L4, L5
- Largest branch of lumbar plexus
- Exits plexus at lower psoas muscle
- Travels in groove between psoas and iliacus muscles
- Exits pelvis beneath inguinal ligament, lateral to femoral vessels, enters femoral triangle
- Multiple branches in femoral triangle
  - Muscular branches: To pectineus, sartorius, rectus femoris, vastus lateralis, vastus medialis, vastus intermedius muscles
  - Cutaneous nerves: Anterior femoral cutaneous, saphenous
    - Saphenous nerve exits triangle, enters adductor canal
  - Articular branches hip and knee

Sciatic Nerve

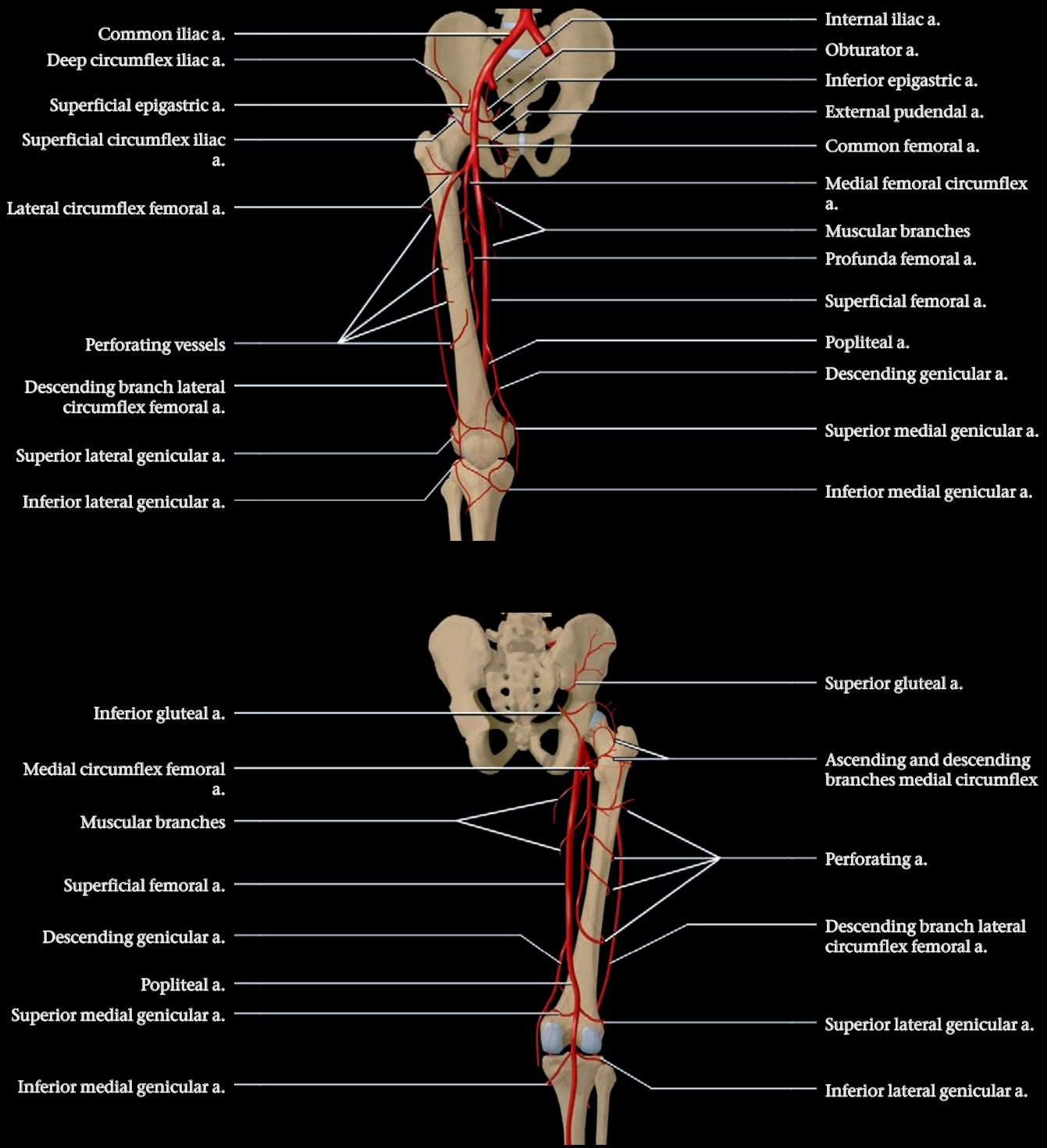
- Nerve contributions from: L4, L5, S1, S2, S3 levels
- Largest nerve in the body
- 2 nerves in 1 sheath
  - Tibial nerve (medial) and common peroneal nerve (lateral)
  - Separate in popliteal fossa
- Course
  - Exits pelvis inferior to piriformis muscle
    - Anomalous relationship in 10%
  - Deep to gluteus maximus muscle, more inferiorly deep to biceps femoris muscle
    - Crosses over superior gemellus, obturator internus, inferior gemellus, quadratus femoris, adductor magnus muscles
    - Midway between ischial tuberosity and greater trochanter in transverse plane
  - Runs deep to long head of biceps femoris muscle after exiting gluteal region
- Branches arising in thigh: Articular to hip, nerves to hamstring muscles
- Supply
  - In thigh: Biceps femoris, semitendinosus, semimembranosus, ischiocondylar portion of adductor magnus muscle
- **Tibial nerve**: Larger division of sciatic nerve
  - Supplies posterior femoral muscles except short head biceps femoris muscle
- **Common peroneal nerve**
  - Oblique lateral course with biceps femoris muscle
  - Supplies short head biceps femoris muscle

ANATOMY IMAGING ISSUES

Imaging Recommendations

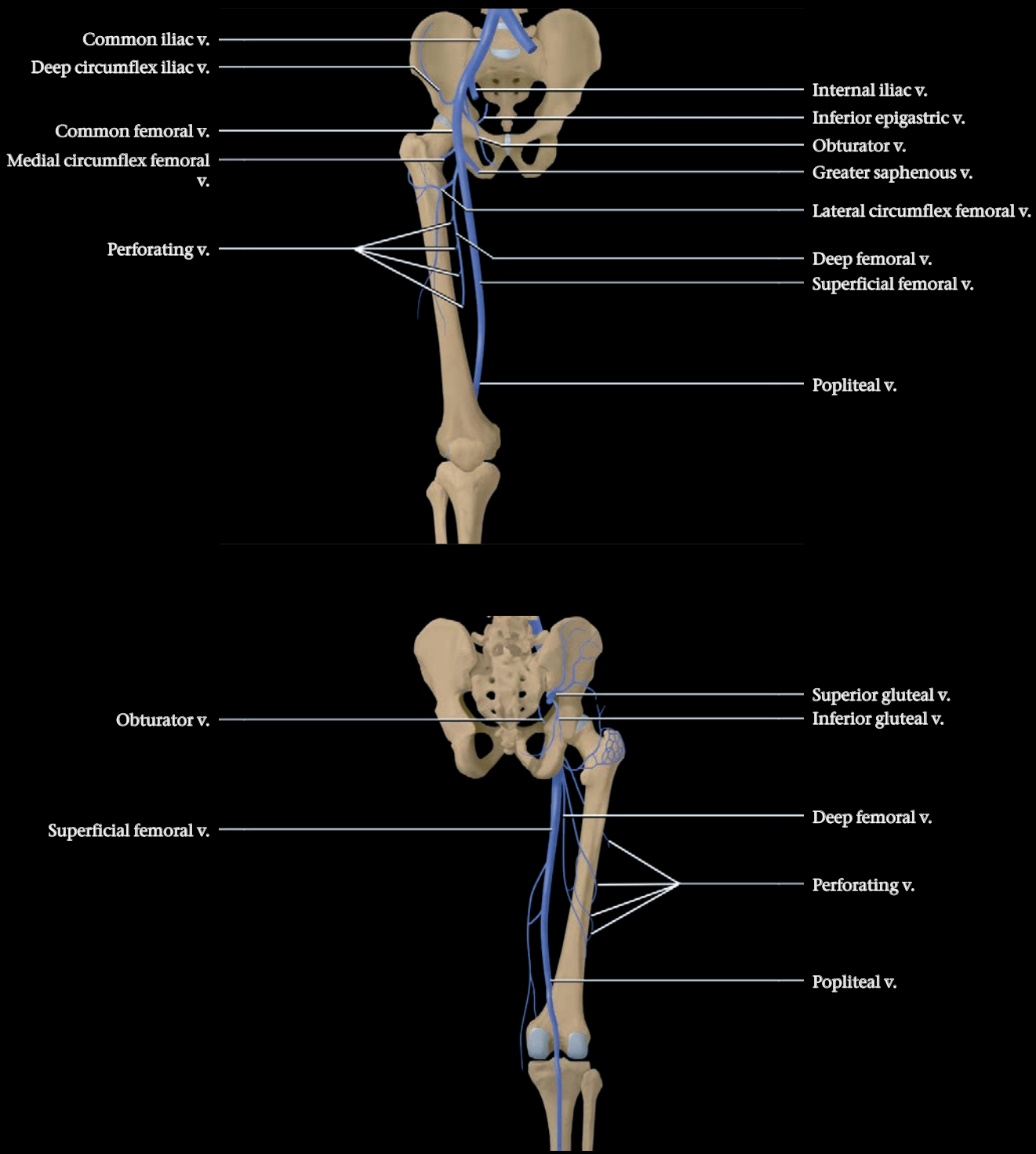
- Ultrasound is unique in that it assesses both morphology and functional response of vessels
  - Complete examination should include interrogation with color Doppler
  - In cases with stenosis, reflux, or reverse flow, spectral Doppler helpful to demonstrate waveform and document flow velocity
  - Dynamic maneuvers, such as transducer compression, breath holding, Valsalva, and calf augmentation are helpful to assess patency of veins on color and spectral Doppler
  - Intravenous contrast is not necessary
- High spatial resolution makes ultrasound suitable for assessing superficial nerves
  - Disruption of parallel continuity of nerve bundles suggests pathology
  - Transducer angulation may need to be changed to avoid anisotropy

GRAPHICS, THIGH ARTERIES

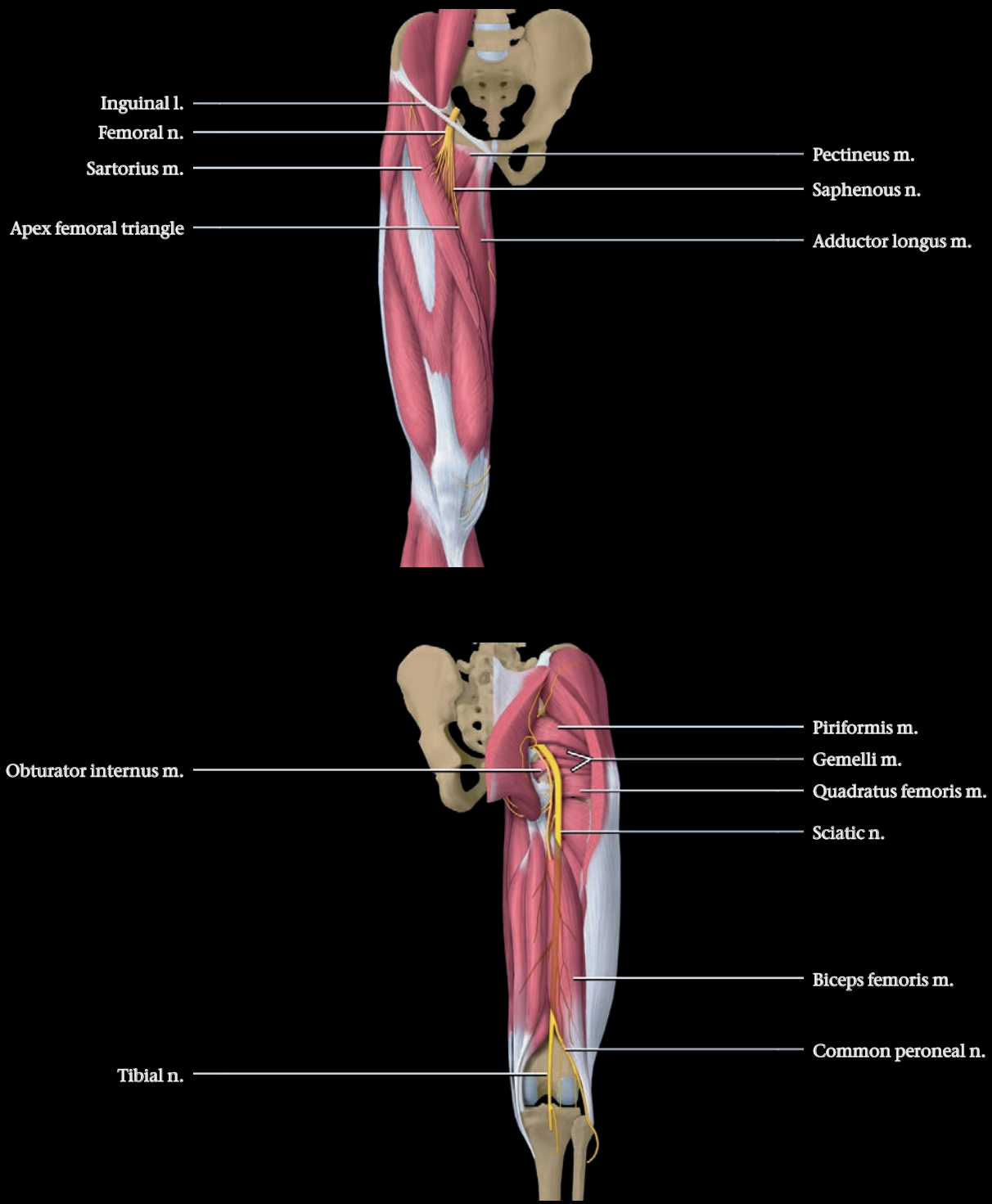


(Top) *Anterior view shows the external iliac, femoral, and popliteal arteries and their branches.* ***(Bottom)*** *Posterior view shows the femoral and popliteal arteries and the superior and inferior gluteal arteries of the greater sciatic notch. All of the main arteries and veins can be readily evaluated with ultrasound. CT angiography or MR angiography are the best investigation to provide an imaging roadmap of the main arteries in the lower limb and these investigation have replaced standard angiography in this respect. Standard digital subtraction angiography (DSA) is still the best investigation to demonstrate the smaller arteries of the lower limb (such as those around of the feet or around the hip).*

GRAPHICS, THIGH VEINS



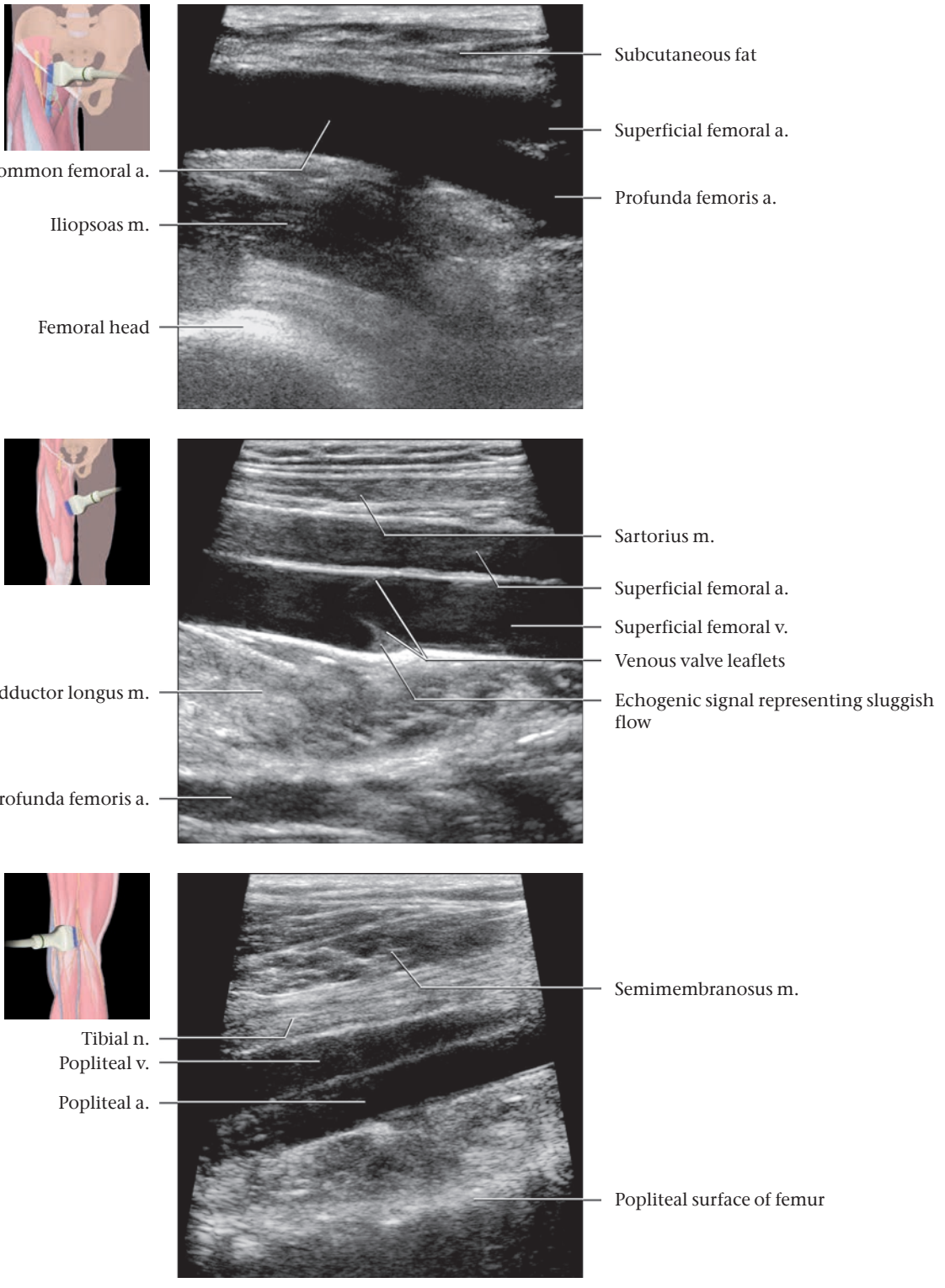
(Top) *Anterior view shows the veins of the thigh. The veins typically follow the arterial tree. The main venous drainage is the superficial femoral vein, which is actually a deep venous structure. Note the entrance of the greater saphenous vein into the femoral vein; the saphenous venous system has no accompanying artery.* ***(Bottom)*** *Posterior view shows the veins of the thigh and buttocks. The veins generally follow the arterial tree, although more variability is seen within the venous system.*



(Top) *Femoral nerve is shown. After emerging from the groove between the psoas and iliacus muscles, the nerve passes under the inguinal ligament to enter the femoral triangle. It immediately branches into muscular, cutaneous, and articular nerves. The only nerve to pass through the femoral triangle into the adductor canal is the saphenous nerve.* ***(Bottom)*** *The sciatic nerve enters the lower extremity by passing under the inferior border of the piriformis muscle. The sciatic nerve passes posterior to the external rotator muscles and then courses deep to the biceps femoris muscle. It separates into the tibial and common peroneal nerves in the distal thigh. The tibial nerve bisects the popliteal fossa. The common peroneal nerve follows the biceps femoris muscle around the fibular head.*

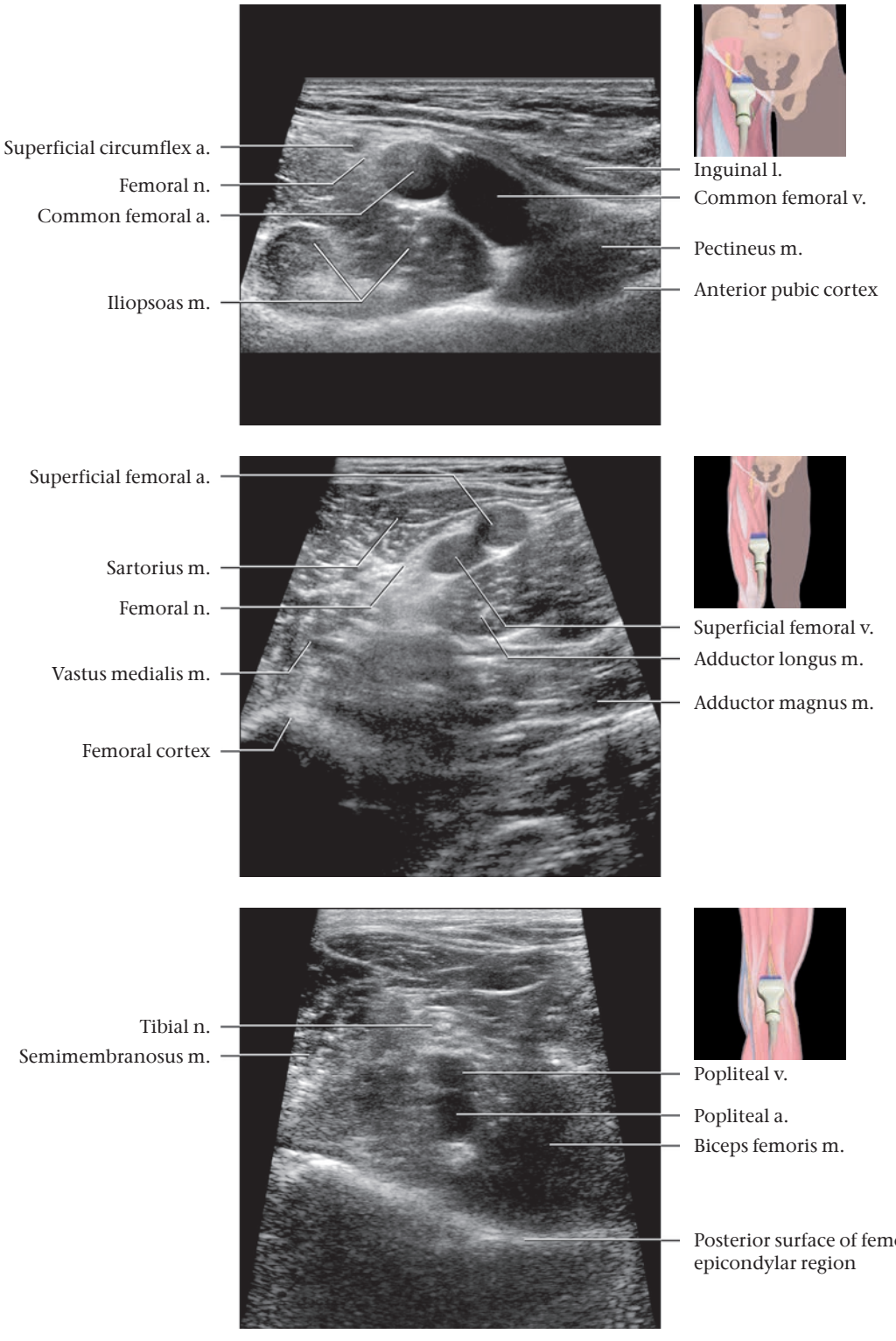
FEMORAL VESSELS AND NERVES

LONGITUDINAL THIGH VESSELS



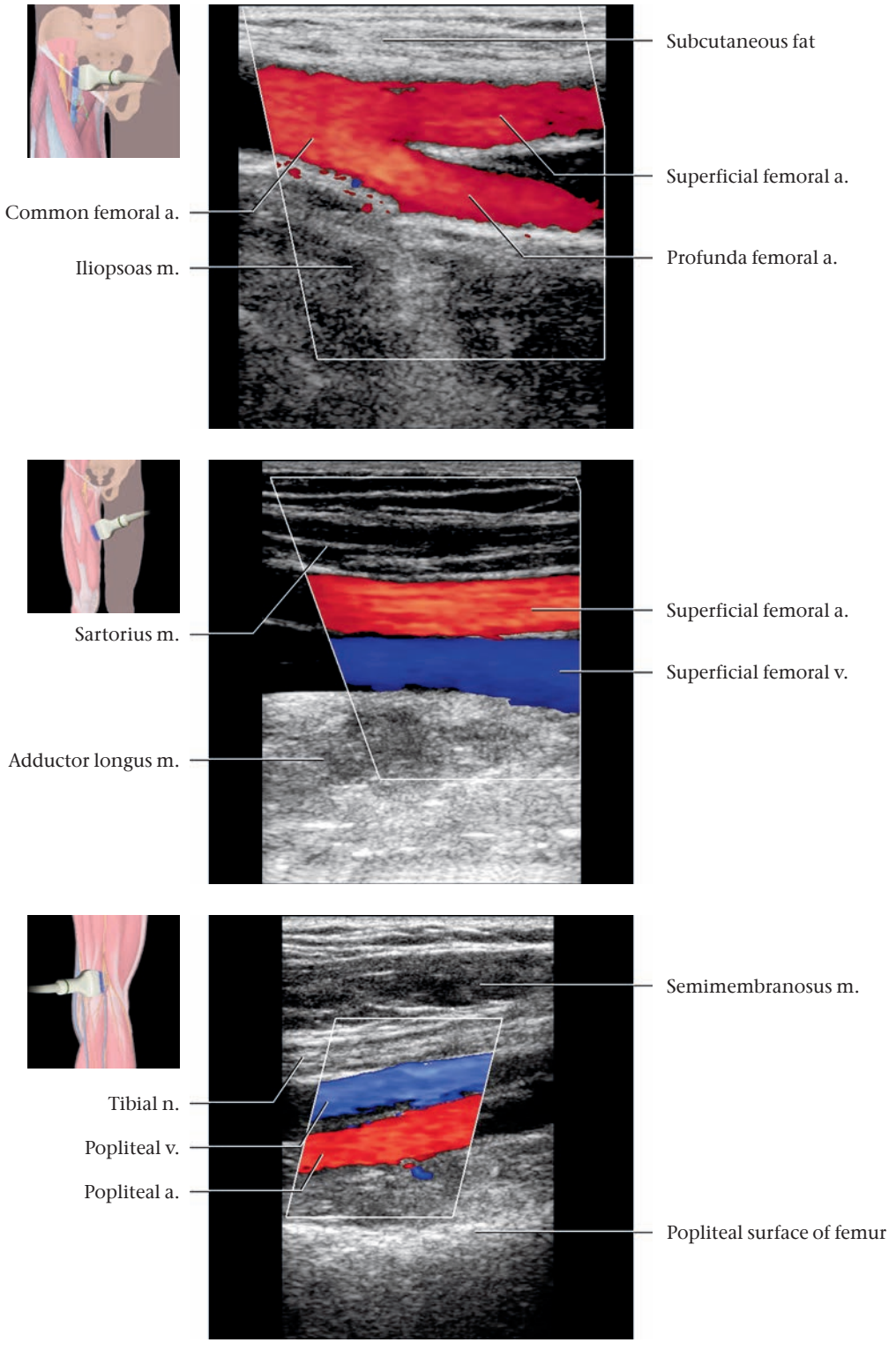
(Top) *Sagittal scan shows the common femoral artery and its bifurcation into the superficial femoral artery and the profunda femoral artery. The superficial femoral artery continues into the femoral triangle and adductor canal before ending at the adductor hiatus to become the popliteal artery. The profunda femoris artery supplies the muscles of the thigh.* ***(Middle)*** *Sagittal scan shows the upper adductor canal. The superficial femoral vessels are covered by the sartorius muscle. The high spatial resolution of ultrasound allows venous valves and sluggish flow to be visualized (the latter as increased echogenicity).* ***(Bottom)*** *Sagittal scan shows the popliteal vessels using a posterior approach. Note the reversed relationship between the vessels: The vein now lies more superficially than the artery.*

TRANSVERSE THIGH VESSELS



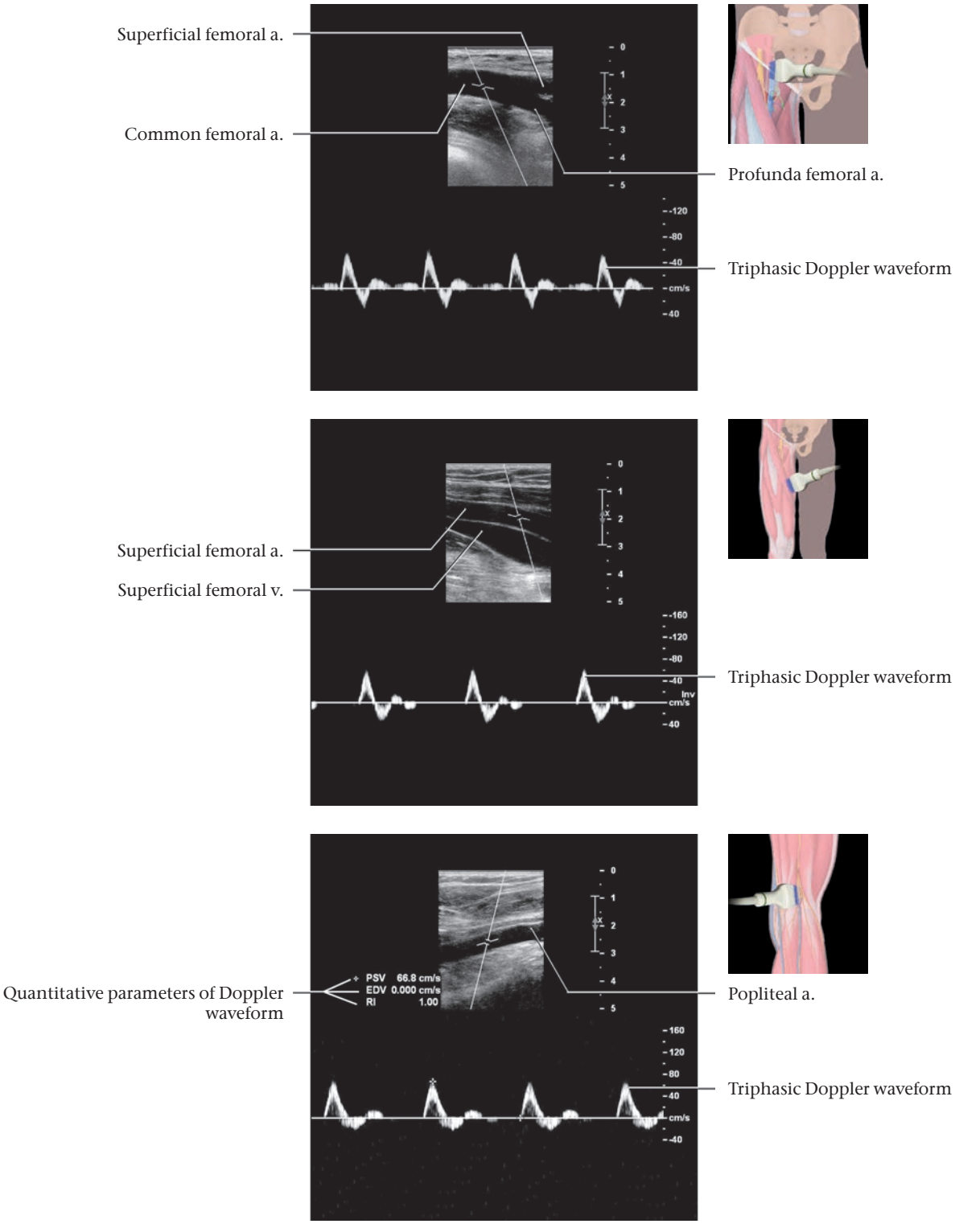
(Top) *Transverse scan shows the common femoral vessels emerging from under the inguinal ligament. The femoral nerve lies lateral to the common femoral artery. The iliopsoas muscle and pectineus muscle form the floor.* ***(Middle)*** *Transverse scan shows the lower aspect of the femoral triangle. The sartorius begins to cover the femoral vessels. The vastus medialis and the adductor longus muscles form the side walls of the femoral triangle. More inferiorly, the common femoral vessels bifurcate into the superficial and profunda branches.* ***(Bottom)*** *Transverse scan shows the posterior thigh at the upper level of the popliteal fossa. After passing through the adductor hiatus, the superficial femoral vessels enter the popliteal fossa. The hamstring muscles form the side walls of this fossa.*

COLOR DOPPLER THIGH ARTERY



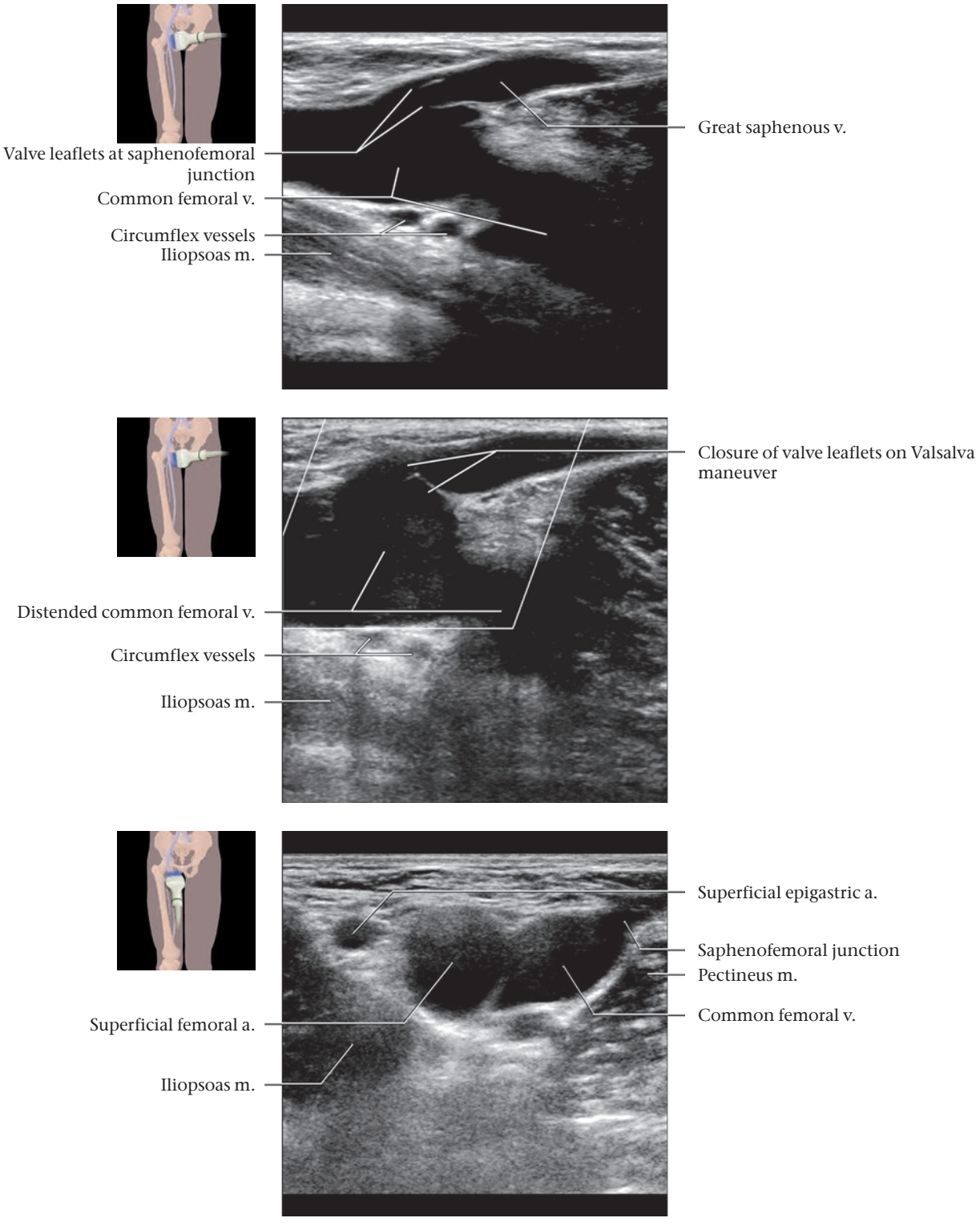
(Top) *Sagittal color Doppler scan shows the common femoral bifurcation. Color, representing flow, should fill the entire lumen with appropriate scan settings (as seen in this image).* ***(Middle)*** *Sagittal color Doppler scan shows the superficial femoral vessels in the upper adductor canal. The color of flow is direction dependent (the Doppler effect) and here demonstrates the opposite direction of flow between the artery (red, away from the trunk) and vein (blue, toward the trunk). Again, the color should fill the entire lumen (red superficial to blue).* ***(Bottom)*** *Sagittal color Doppler scan shows the popliteal vessels using a posterior approach. The vein now lies superficial to the artery (blue superficial to red).*

SPECTRAL DOPPLER THIGH ARTERIES



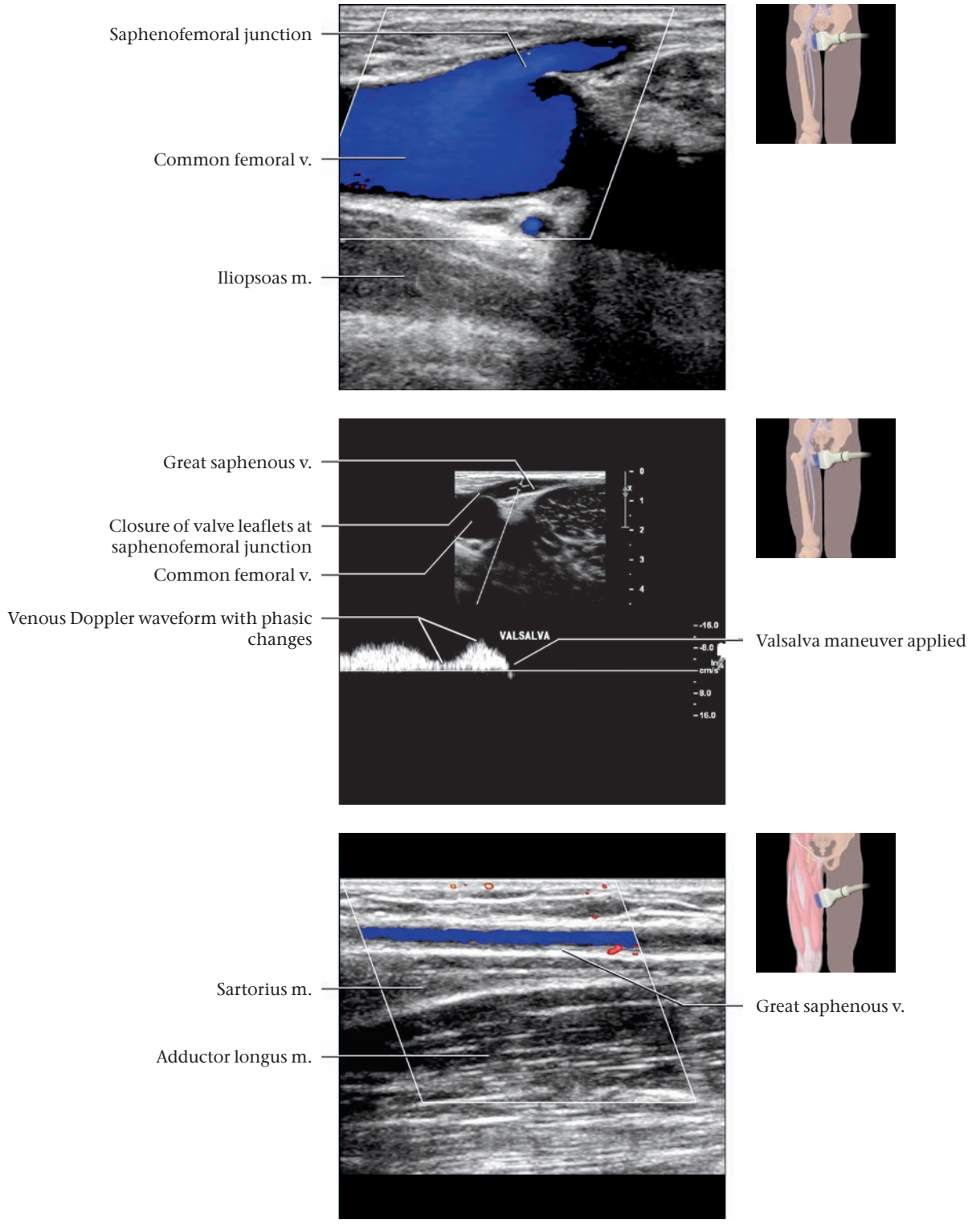
(Top) *Spectral Doppler trace at the common femoral artery is shown. The typical waveform for an artery should be triphasic: Forward sharp upstroke of forward flow (systolic), then reverse flow (early diastolic), and finally slow forward flow (late diastolic), as seen in this trace.* ***(Middle)*** *Spectral Doppler trace performed at the superficial femoral artery shows a similar waveform and slight decrease in the peak systolic flow. In general, as one moves further away from the heart, the peak velocity decreases.* ***(Bottom)*** *The typical arterial waveform is again seen in a spectral Doppler trace of the popliteal artery.*

SAPHENOFEMORAL JUNCTION



(Top) *Sagittal scan at the confluence of the great saphenous vein with the common femoral vein is shown. On this image, the valve at the saphenofemoral junction is open to allow blood from the great saphenous vein to drain into the common femoral vein.* ***(Middle)*** *Sagittal color Doppler scan shows the saphenofemoral junction during a Valsalva maneuver. The increased abdominal pressure is transmitted in the common femoral vein. This closes the valve at the saphenofemoral junction to prevent reflux into the great saphenous vein and also distends the common femoral vein (seen here as an increase in caliber). The lack of color flow across the valve indicates that the valve is competent.* ***(Bottom)*** *Transverse scan shows the saphenofemoral junction. The great saphenous vein penetrates the femoral sheath to enter the common femoral vein.*

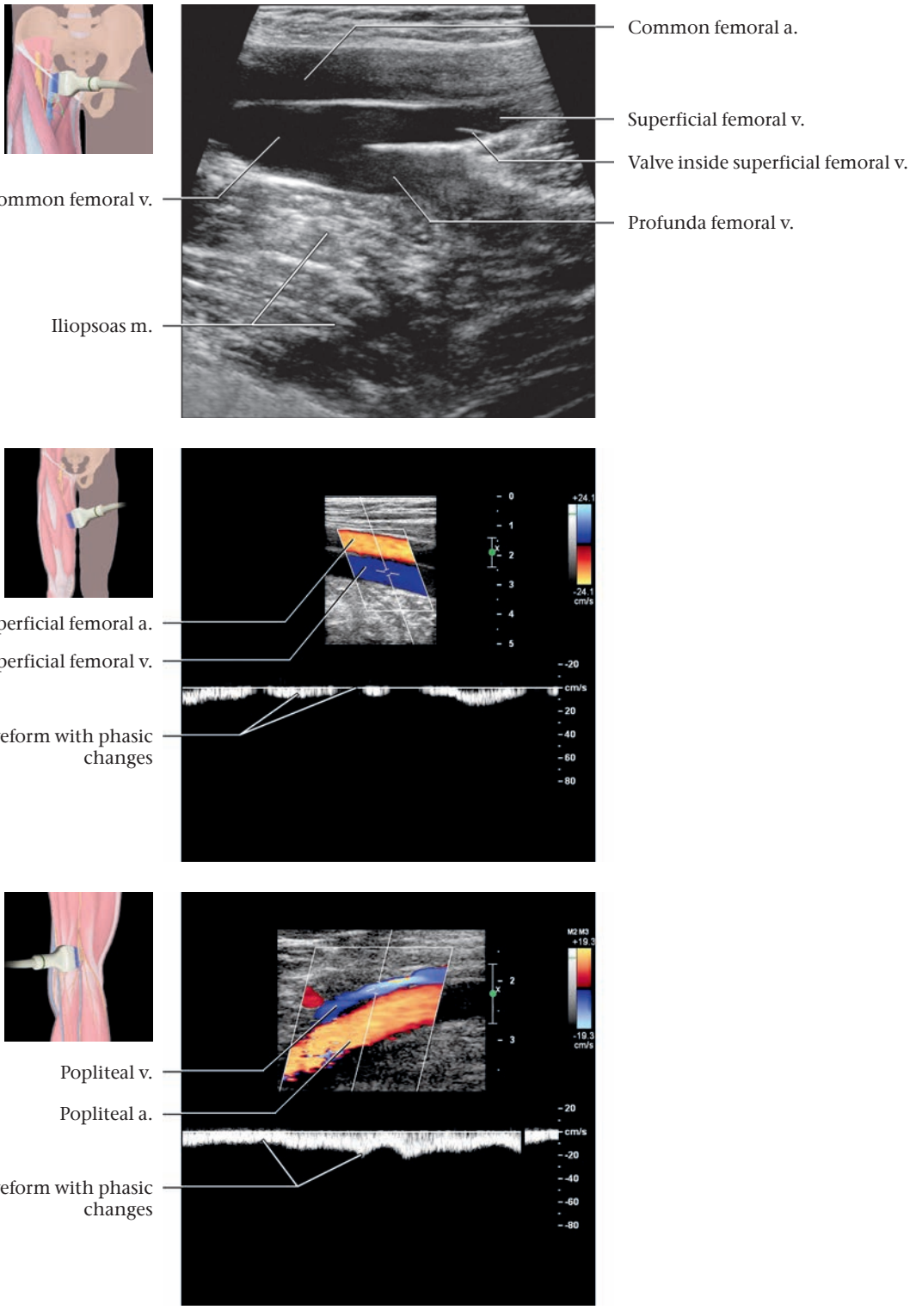
DOPPLER SAPHENOUS VEIN



(Top) *Sagittal color Doppler scan shows the saphenofemoral junction. The color flow in both the great saphenous vein and the common femoral vein is toward the trunk.* ***(Middle)*** *Spectral Doppler trace of the great saphenous vein before and during a Valsalva maneuver is shown. The normal venous Doppler spectrum is biphasic due to respiratory variations. Applying a Valsalva maneuver, the valve closes abruptly at the saphenofemoral junction and stops flow in the great saphenous vein, which is seen as a zero flow velocity on the trace.* ***(Bottom)*** *Oblique coronal color Doppler scan of the great saphenous vein in the medial thigh shows blood flow toward the trunk (correct direction).*

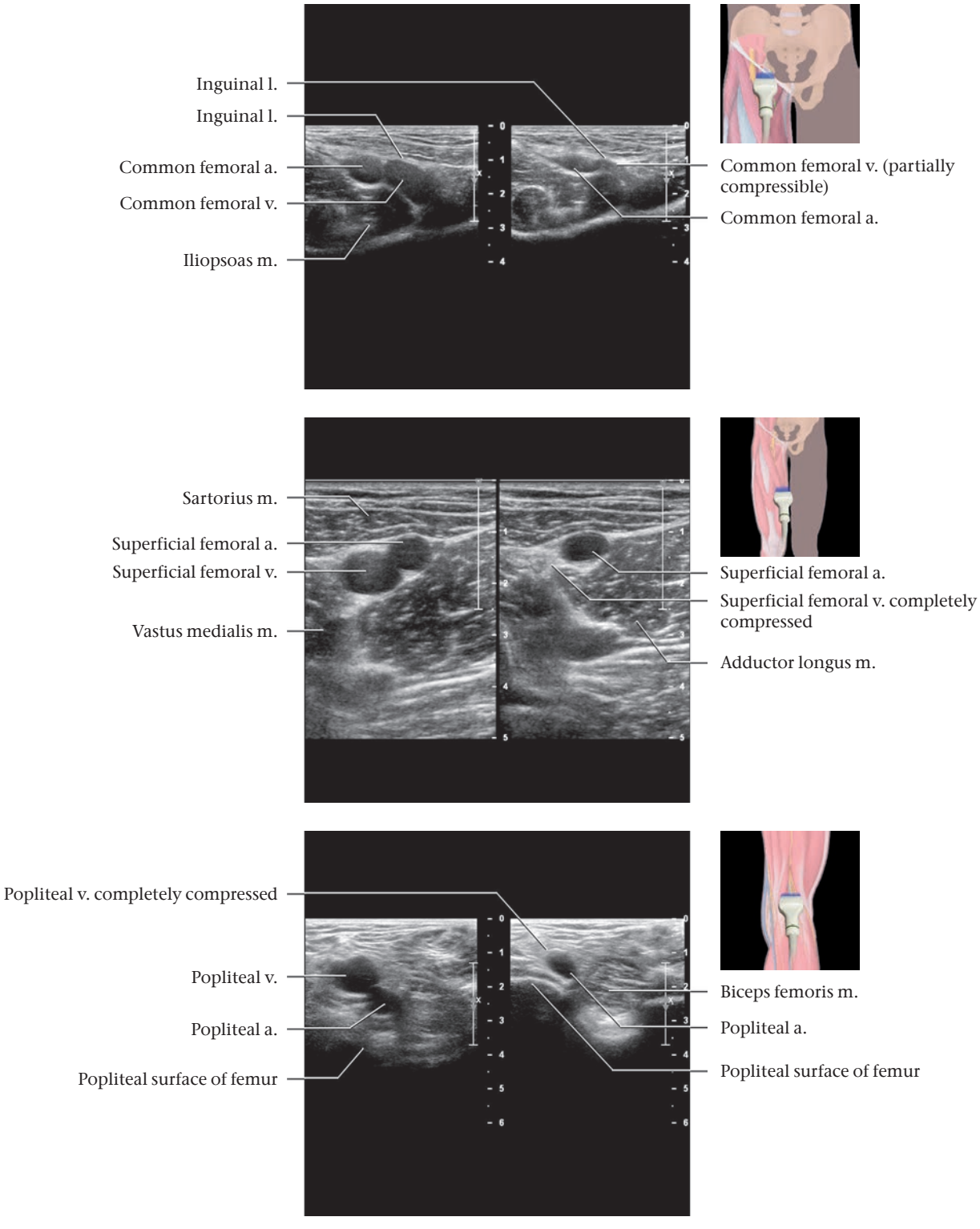
FEMORAL VESSELS AND NERVES

THIGH VEIN



(Top) *Sagittal scan shows the confluence of the common femoral vein. The common femoral vein is formed by its main tributaries: The superficial femoral vein and the profunda femoral vein (both accompanying the course of the arteries of the same name).* ***(Middle)*** *Spectral Doppler trace shows the superficial femoral vein. The normal venous Doppler waveform is biphasic and varies with the phase of respiration. The flow velocity is also much slower than that in the artery.* ***(Bottom)*** *Spectral Doppler trace of the popliteal vein shows a similar venous waveform with respiratory phasic changes.*

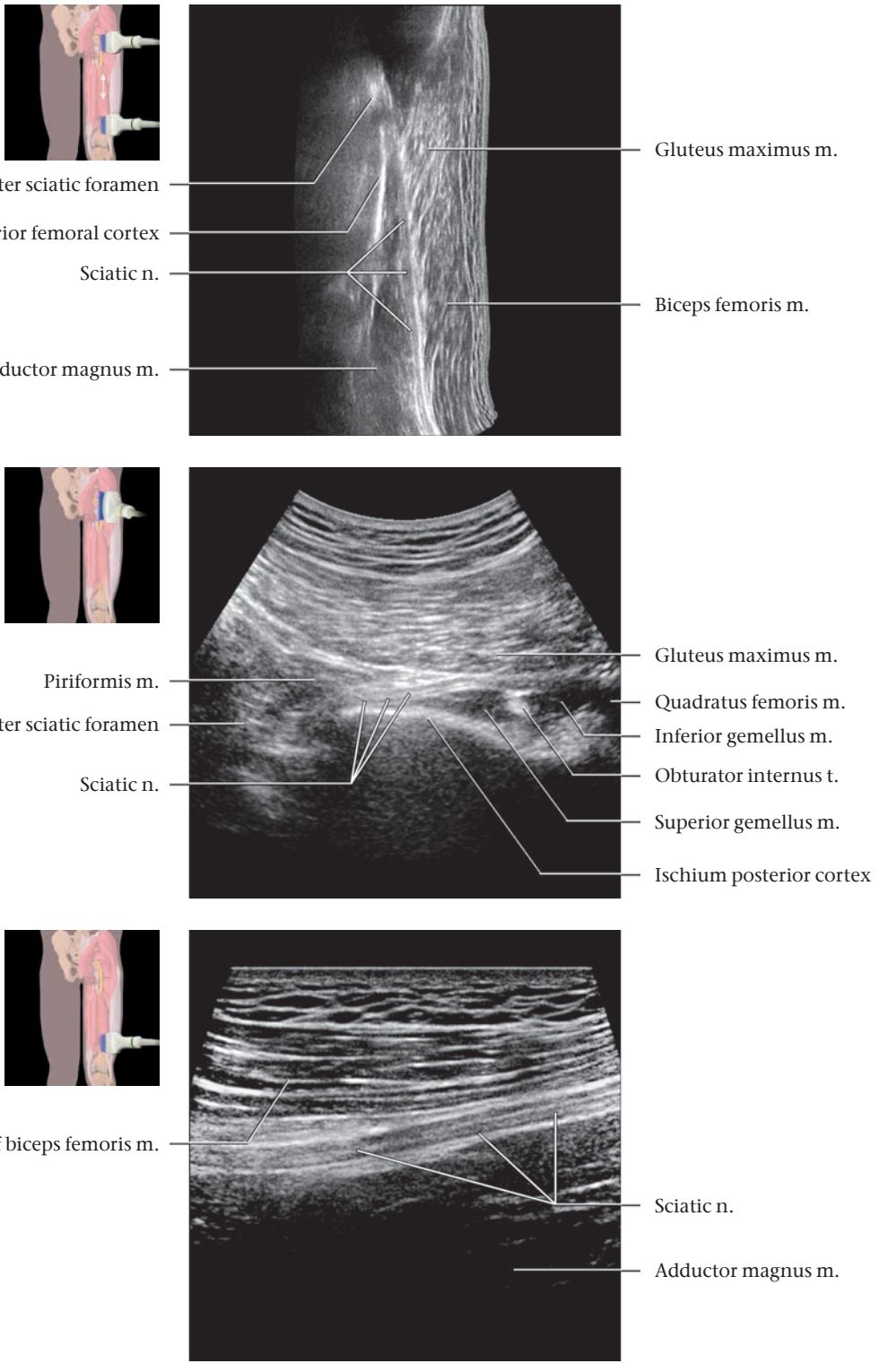
FEMORAL VEIN: COMPRESSION



(Top) *Pre-/postcompression split screen transverse scan shows the common femoral vessels. The left 1/2 of the image is obtained applying normal gentle transducer pressure, the right 1/2 scanned with firm compression. Patent veins are normally compressible with firm transducer pressure, with the exception demonstrated here due to the inguinal ligament. This is not a sign of venous thrombosis.* ***(Middle)*** *Pre-/postcompression split screen transverse scan in the adductor canal shows the normal compressible superficial femoral vein. With firm pressure, the superficial artery is distorted, but the lumen is not obliterated.* ***(Bottom)*** *Pre-/postcompression split screen transverse scan of the popliteal vessels show the same response: Obliterated venous lumen and distorted arterial lumen.*

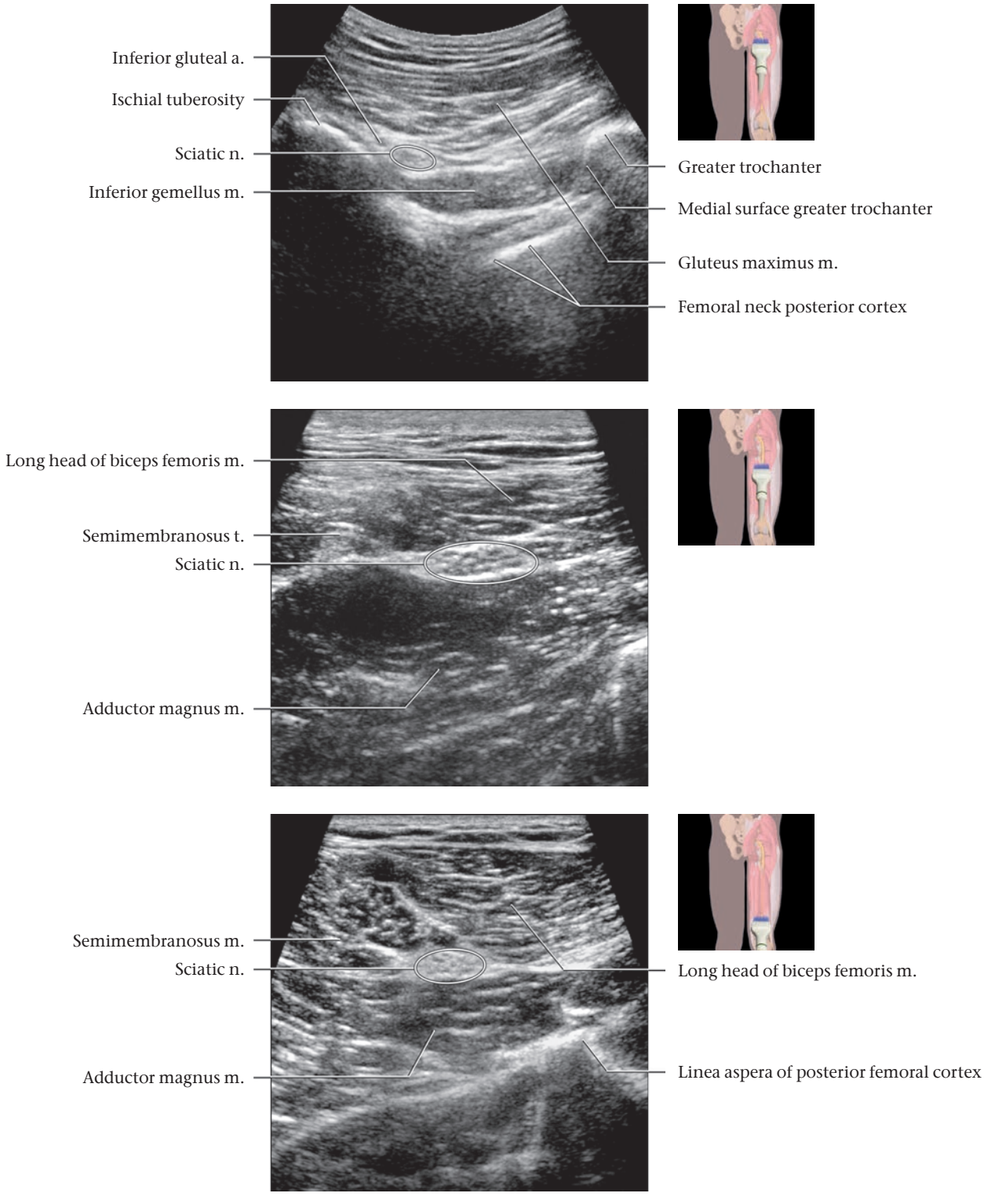
FEMORAL VESSELS AND NERVES

SCIATIC NERVE



(Top) *Longitudinal panoramic view of the sciatic nerve shows its course after it has exited the greater sciatic foramen. It runs distally deep to the gluteus maximus and then deep to the biceps femoris to the popliteal fossa.* ***(Middle)*** *Sagittal scan shows the greater sciatic foramen using the ischial tuberosity as a landmark. The sciatic nerve and its relationship with the small external rotators of the hip is shown here. The sciatic nerve emerges between the piriformis and superior gemellus muscles after passing through the greater sciatic foramen.* ***(Bottom)*** *This longitudinal view of the sciatic nerve demonstrates the parallel and uniform hypoechoic tracts (representing nerve bundles). Any disruption of the uniformity or parallel course should be considered abnormal.*

TRANSVERSE SCIATIC NERVE



(Top) *Transverse scans at 3 different levels show the sciatic nerve. The sciatic nerve, after it has exited the greater sciatic foramen, passes superficial to the small external rotators of the hip joint (obturator internus, superior and inferior gemelli, and quadratus femoris). The inferior gluteal artery lies medial to the nerve.* ***(Middle)*** *At the upper thigh level, the sciatic nerve is covered by the long head of the biceps femoris muscle and is relatively superficial. The high spatial resolution of ultrasound allows individual nerve bundles to be identified as black dots in a bright matrix of epineurium.* ***(Bottom)*** *The same relationship with the long head of biceps femoris muscle continues inferiorly down the thigh until the sciatic nerve divides into the peroneal nerves.*

KNEE

TERMINOLOGY

Abbreviations

- Artery (a.), function (F), ligament (l.), medial collateral ligament (MCL), muscle (m.), tendon (t.), vein (v.), origin (O), insertion (I)

GROSS ANATOMY

Overview

- Largest and most complex joint
  - Hinge joint throughout its greatest range of motion
  - Bones do not interlock; stability is maintained by ligaments, tendons, capsule, and menisci
- **Motion** of knee and relationship of osseous structures
  - In full flexion
    - Posterior surfaces of femoral condyles articulate with posterior tibial condyles
    - Lateral facet of patella is in contact with lateral femoral condyle
    - Supporting ligaments are not taut, and rotation of leg is allowed
  - During motion of extension
    - Patella slides upward on femur, engaging with femoral trochlea
    - Femoral condyles roll forward on tibial condyles and menisci
    - Lateral femoral condyle is shorter anteroposteriorly than medial and reaches full extension earlier
    - Medial tibial condyle continues to slide after lateral stops, rotates slightly laterally on femur and medial meniscus ("screwing it home")
    - This tightens cruciate ligaments turning knee into rigid pattern
  - Initiating flexion from fully extended knee
    - Requires slight medial rotation of tibia, produced by popliteus muscle
    - "Unlocks" joint, allowing remainder of motion to take place
- **Muscles acting on knee joint**
  - **Extensors**: 4 parts of quadriceps femoris
    - I: Patella
    - F: Acts together for hip flexion and knee extension
  - Rectus femoris
    - O: Anterior inferior iliac spine
  - Vastus medialis
    - O: Medial shaft of femur
  - Vastus intermedius
    - O: Anterior shaft of femur
  - Vastus lateralis
    - O: Lateral shaft of femur
  - Biceps femoris
    - O: Ischial tuberosity
    - I: Fibular head and tibia
    - F: Crosses both hip and knee joints, extending hip and flexing knee
  - **Flexors**
  - Popliteus
    - O: Arises as tendon from popliteal groove at lateral femoral condyle
    - I: Posterior surface tibia
    - F: Flexes knee and medially rotates tibia at beginning of flexion
  - Sartorius
    - O: Anterior superior iliac spine
    - I: Anteromedial tibia
    - F: Flexes both hip and knee joints, rotating thigh laterally
  - Gracilis
    - O: Pubis
    - I: Anteromedial tibia
    - F: Adducts thigh, flexes knee, and rotates flexed leg medially
  - Semitendinosus
    - O: Ischial tuberosity
    - I: Anteromedial tibia
    - F: Extends hip, flexes knee, medially rotates flexed leg
  - Semimembranosus
    - O: Ischial tuberosity
    - I: Posterior medial condyle tibia
    - F: Extends hip, flexes knee, medially rotates flexed knee

IMAGING ANATOMY

Osseous Anatomy

- **Distal femur**
  - Distal femoral metaphysis flares into medial and lateral epicondyles
  - Medial femoral condyle larger than lateral
  - Anteriorly, trochlear groove accommodates patella and is generally V-shaped
- **Proximal tibia**
  - Gerdy tubercle anterolateral just distal to joint
  - Tibial tubercle (apophysis) anterior and slightly lateral, several cm distal to joint
- **Proximal fibula**
  - Posterolateral relative to tibia
  - Fibular styloid process
- **Tibiofibular joint**
  - True synovial joint; subject to any arthritic process
  - Connects to knee joint in 20%
- **Patella**
  - Triangular sesamoid
  - Wider at base superiorly than at apex inferiorly
  - Nonarticular outer surface may develop prominent enthesopathy where quadriceps tendon insertion blends into origin of inferior patellar tendon
  - Bipartite (multipartite) patella: Always upper outer quadrant; osseous fragments may not appear to "match," but cartilage is continuous over defect

Articular Capsule

- Highly complex, noncontiguous structure
- Contributions from multiple muscles, tendons, and ligaments

Extensor Mechanism

- **Quadriceps**
  - Composed of rectus femoris: Vastus lateralis, medialis, and intermedius muscles
  - Quadriceps tendon inserts on anterior surface of patella
  - Patellar tendon is mainly composed of rectus femoris fibers that course over patella
  - Patellar tendon runs from inferior pole of patellar to tibial tuberosity
  - Fibers of vastus lateralis and medialis contribute to lateral and medial retinacula, respectively

Fat Pads

- Suprapatellar: Anterior and posterior to suprapatellar bursa
- Infrapatellar (Hoffa fat pad): Inferior to patella and between patellar ligament and anterior knee joint
- Posterior: Around joint margin extending into intercondylar region

Medial Supporting Structures

- Superficial (layer 1)
  - Pes anserinus: Anteromedial tibial insertion
    - Sartorius embedded in crural fascia
    - Gracilis immediately deep to sartorius
    - Semitendinosus immediately deep to gracilis
- Middle (layer 2)
  - Superficial medial collateral ligament (longitudinal and oblique components)
    - Origin: Medial epicondyle; runs slightly anteromedially to insert on tibia 5 cm distal to joint line
    - Anteriorly, longitudinal component fascia blends with layer 1
    - Posteriorly, oblique component blends with layer 3 as posterior oblique ligament
- Deep (layer 3)
  - Capsular layers (sometimes termed deep fibers of MCL) at midportion of knee
    - Meniscofemoral ligament: From outer superior aspect of body of meniscus to either superficial MCL or femur
    - Meniscotibial (coronary) ligament: From outer inferior aspect of body of meniscus to tibia just distal to joint line
  - More posteriorly, superficial MCL blends with capsular layers MCL
  - Posterior oblique ligament arises from superficial MCL
    - Blends with posteromedial meniscus
    - Receives fibers from semimembranosus tendon
    - Envelops posterior aspect of femoral condyle, termed oblique popliteal ligament

Lateral Supporting Structures

- Superficial (layer 1)
  - Iliotibial band anteriorly, inserting on Gerdy tubercle
  - Superficial portion biceps femoris posterolaterally, inserting on fibular styloid
- Middle (layer 2)
  - Quadriceps retinaculum anteriorly
  - Posteriorly, 2 ligamentous thickenings, which originate from lateral patella
    - Proximal: Terminates at lateral intermuscular septum on femur
    - Distal: Terminates at femoral insertion of posterolateral capsule and lateral head of gastrocnemius
- Deep (layer 3): Several thickenings in lateral part of capsule function as discrete structures
  - Lateral (fibular) collateral ligament originates from lateral femoral epicondyle, extends posterolaterally to insert on lateral fibular head
  - Arcuate ligament originates from styloid process of fibular head, interdigitates with popliteus, and inserts into posterior capsule near oblique popliteal ligament
  - Several other small and inconstant structures are located posterolaterally, which are difficult to differentiate by imaging

Internal Structures

- **Menisci**
  - Cushion, lubricate, and stabilize knee
  - Fibrocartilage
  - Only peripheral portion visualized by ultrasound
  - Medial attached to capsule throughout extent of knee
  - Lateral attached to capsule at anterior horn and far posteriorly, but by fascicles to popliteus at body and posterior horn
- **Cruciate ligaments**
  - Major stabilizing structures to anteroposterior motion
- Cruciate ligaments and central portions of menisci are not well visualized by ultrasound

Synovial Recesses of Knee Joint

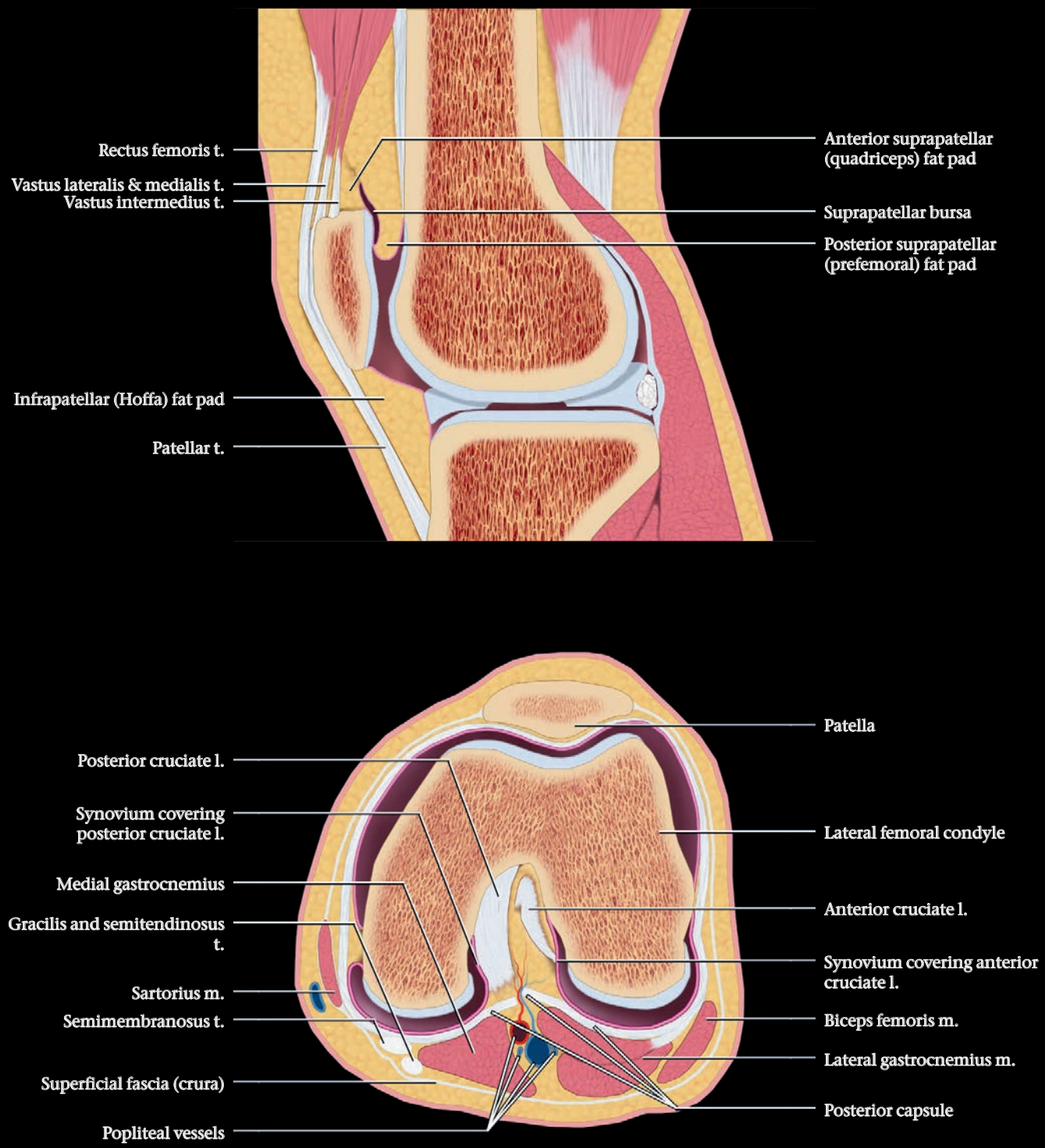
- Suprapatellar, medial patellar, lateral patellar
- Increase in synovial fluid 1st accumulates in either medial or lateral recess and then suprapatellar recess
- Small amount of fluid in knee joint is normal but should not get more than small amount
- Synovial proliferation can also be best assessed at medial and lateral recesses
- Baker cyst is distension of gastrocnemius-semimembraneous bursa
- Slit-like opening occasionally connects knee joint to Baker cyst
- Synovial fluid can be expressed from knee joint into Baker cyst if this interconnection is present

ANATOMY IMAGING ISSUES

Imaging Approaches

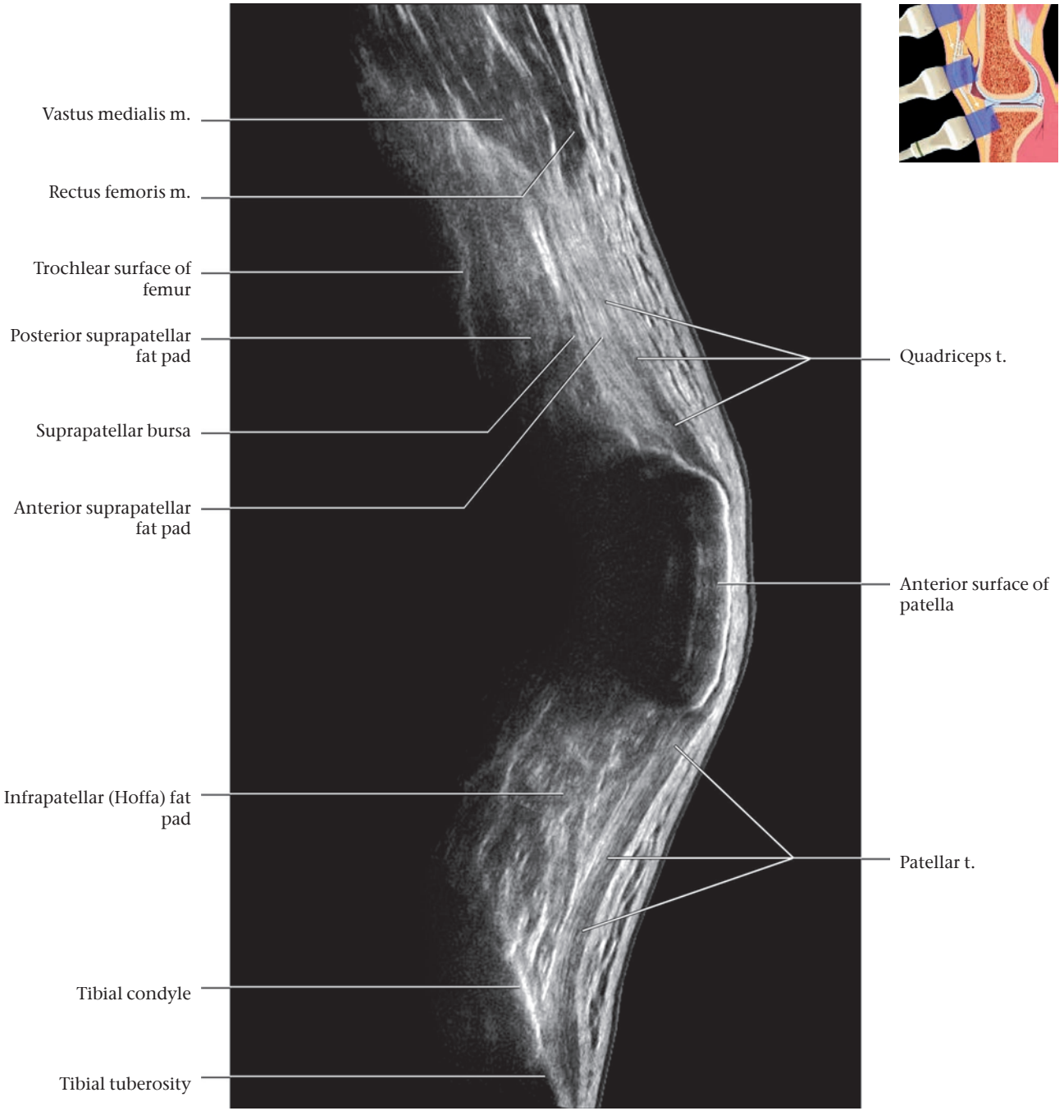
- Ultrasound
  - Good at assessing extracapsular structures and their abnormalities but unable to satisfactorily interrogate internal structures of knee
  - Given the size and complexity of this joint, ultrasound examination needs to be compartmentalized to area of complaint
    - e.g., posterior examination for popliteal mass, lateral examination for suspected iliotibial band syndrome, etc.
  - In an acutely inflamed joint, ultrasound is most effective as a screening tool for effusion, allowing image-guided aspiration concurrently
  - Ultrasound is ideal for assessing extraarticular abnormalities, e.g., tendinosis, ligament disruptions, bursitis, masses, etc.
  - For structures containing fibers, e.g., ligaments and tendons, longitudinal scans tend to be more helpful both in confirming course of structure and assessing integrity
    - For this reason, knee should be flexed during examination of anterior knee
    - Flexion tenses most of the tendinous and ligamentous structures and accentuates straight course of its fibers

GRAPHICS, EXTENSOR MECHANISM



(Top) *Graphic shows trilaminar configuration of the quadriceps tendon. The superficial portion is the rectus femoris, the middle portion is the aponeurosis of the vastus medialis and lateralis, and the deep portion is the vastus intermedius tendon.* ***(Bottom)*** *Graphic shows the relationships of the posterior capsule and overlying structures. The most superficial layer is the crural fascia, which envelops the sartorius and otherwise confines all of the structures. The posterior capsule (white) is continuous with the synovium (pink thin line) both posteromedially and posterolaterally. Superficial to the capsule are the plantaris and gastrocnemius muscles, hamstring muscle and tendons, and the popliteal vessels.*

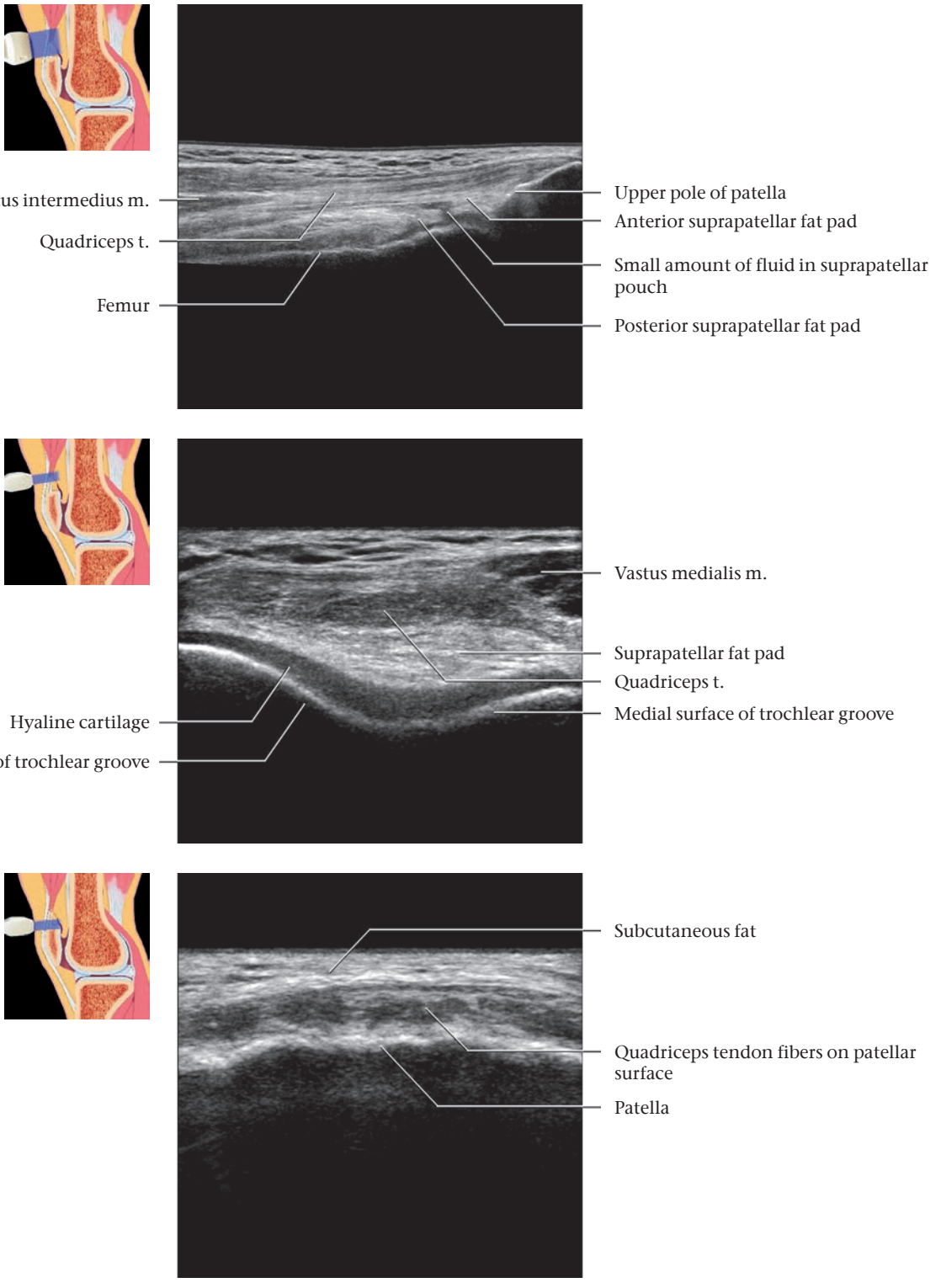
EXTENSOR MECHANISM



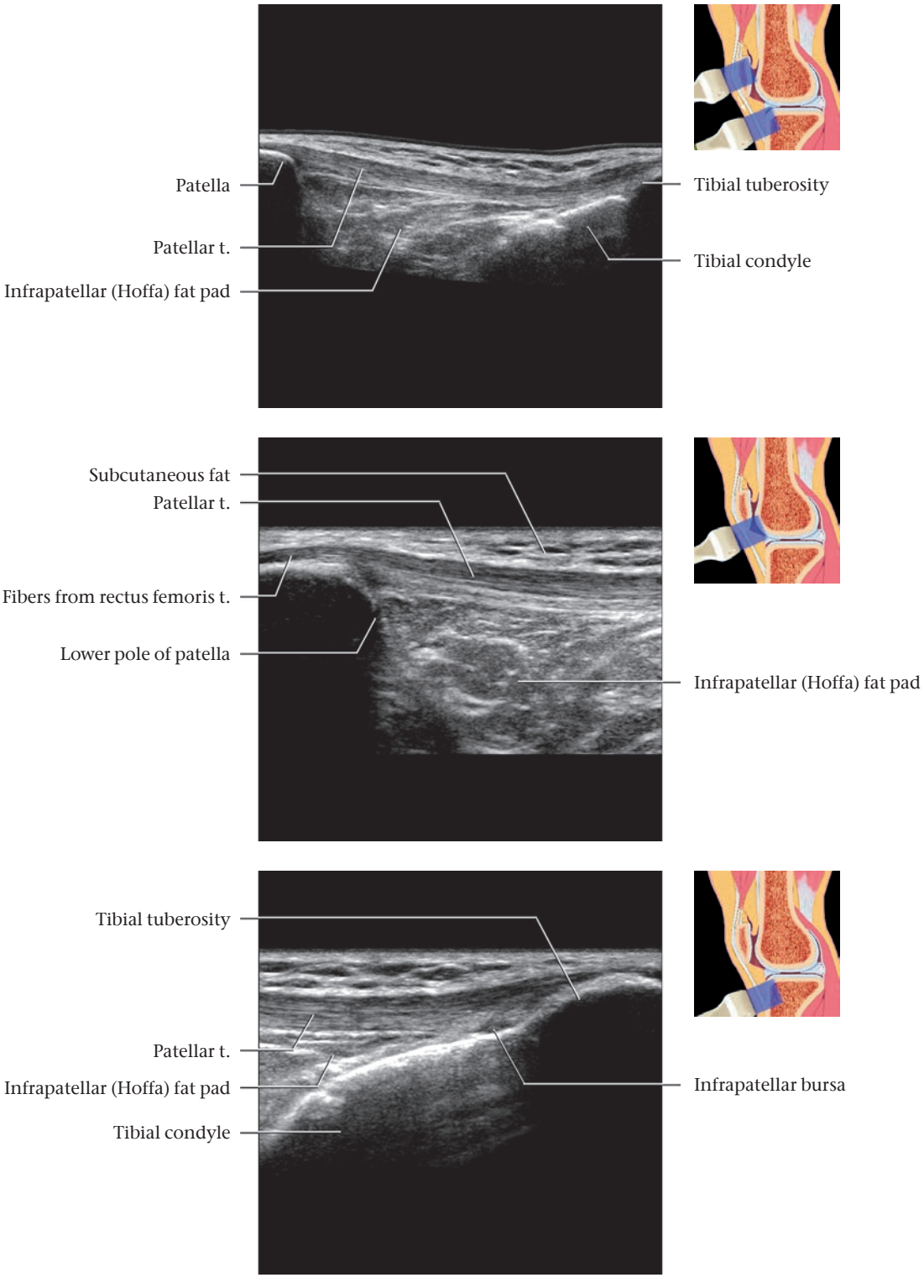
Sagittal panoramic scan of the anterior knee shows the main components of the extensor mechanism: Quadriceps muscle and tendon, patella, and patellar tendon. The scan performed here is with the knee in extension. More focused views of individual components of the anterior knee can be performed with the knee in flexion (with a pillow to support the popliteal region). Flexion increases the tension of the extensor mechanism, thus straightening the tendons. This will help highlight abnormalities in terms of tendon alignment and continuity. However, the amount of suprapatellar fluid may be decreased (due to displacement) in flexion, and assessment of the suprapatellar region in extension may be more sensitive in this respect.

KNEE

EXTENSOR MECHANISM



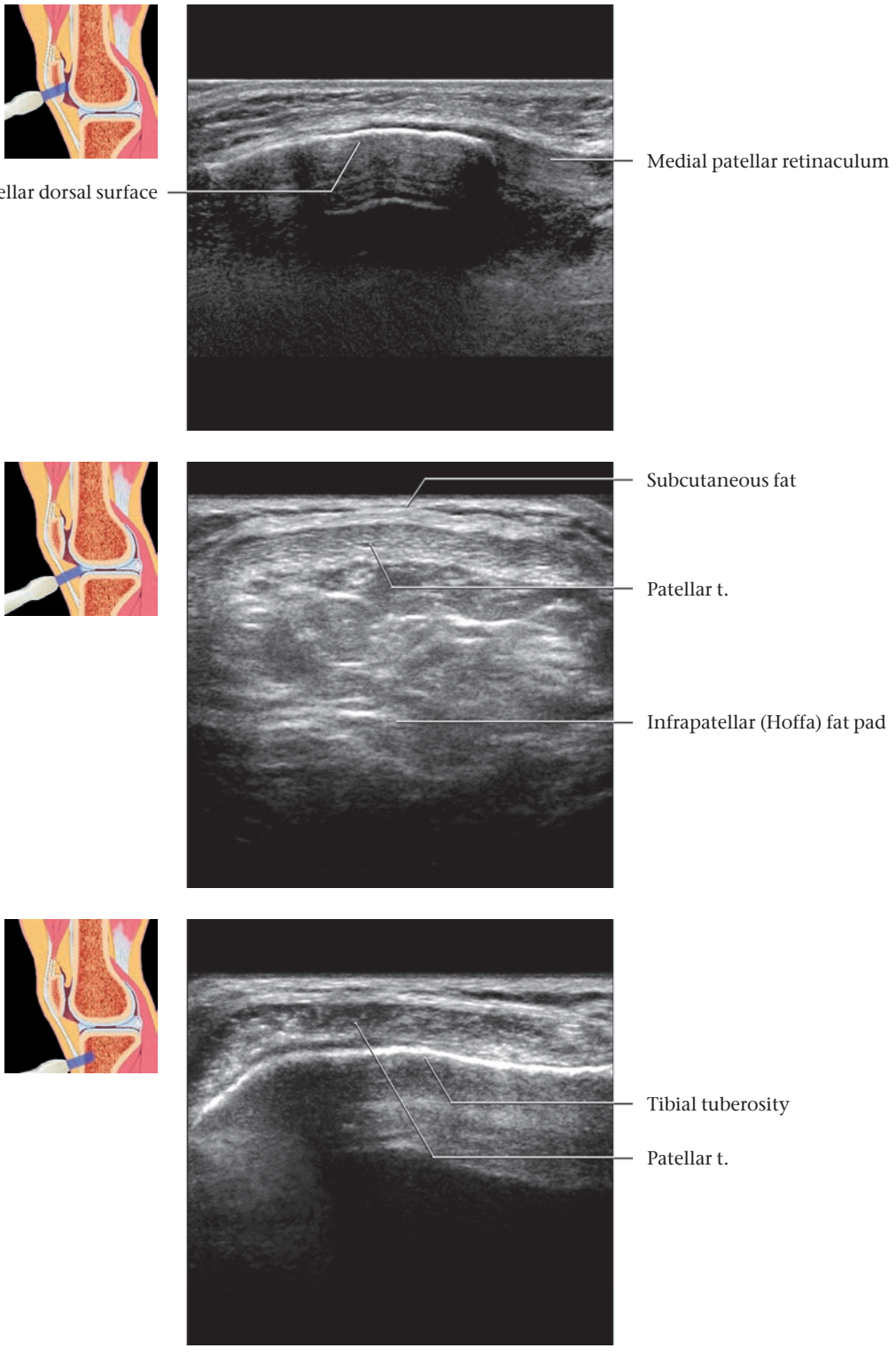
(Top) *Sagittal scan shows the quadriceps tendon. The quadriceps tendon is the direct continuation of the rectus femoris with contributions medially and laterally from the vastus medialis and the vastus lateralis, respectively, and posteriorly from vastus intermedius. The tendon inserts on the superoanterior surface of the patella. In this scan, the suprapatellar pouch can be seen. It may normally contain a small amount of fluid (several millimeters thick).* ***(Middle)*** *Transverse scan shows quadriceps tendon with the knee flexed. The central position of the quadriceps tendon can be appreciated here, receiving contributions from the vastus muscles. The articular cartilage of the trochlear groove can also be seen with the patella out of the way during flexion.* ***(Bottom)*** *Transverse scan of the anterior surface of the patella shows tendon fibers inserting or running on the patellar surface.*



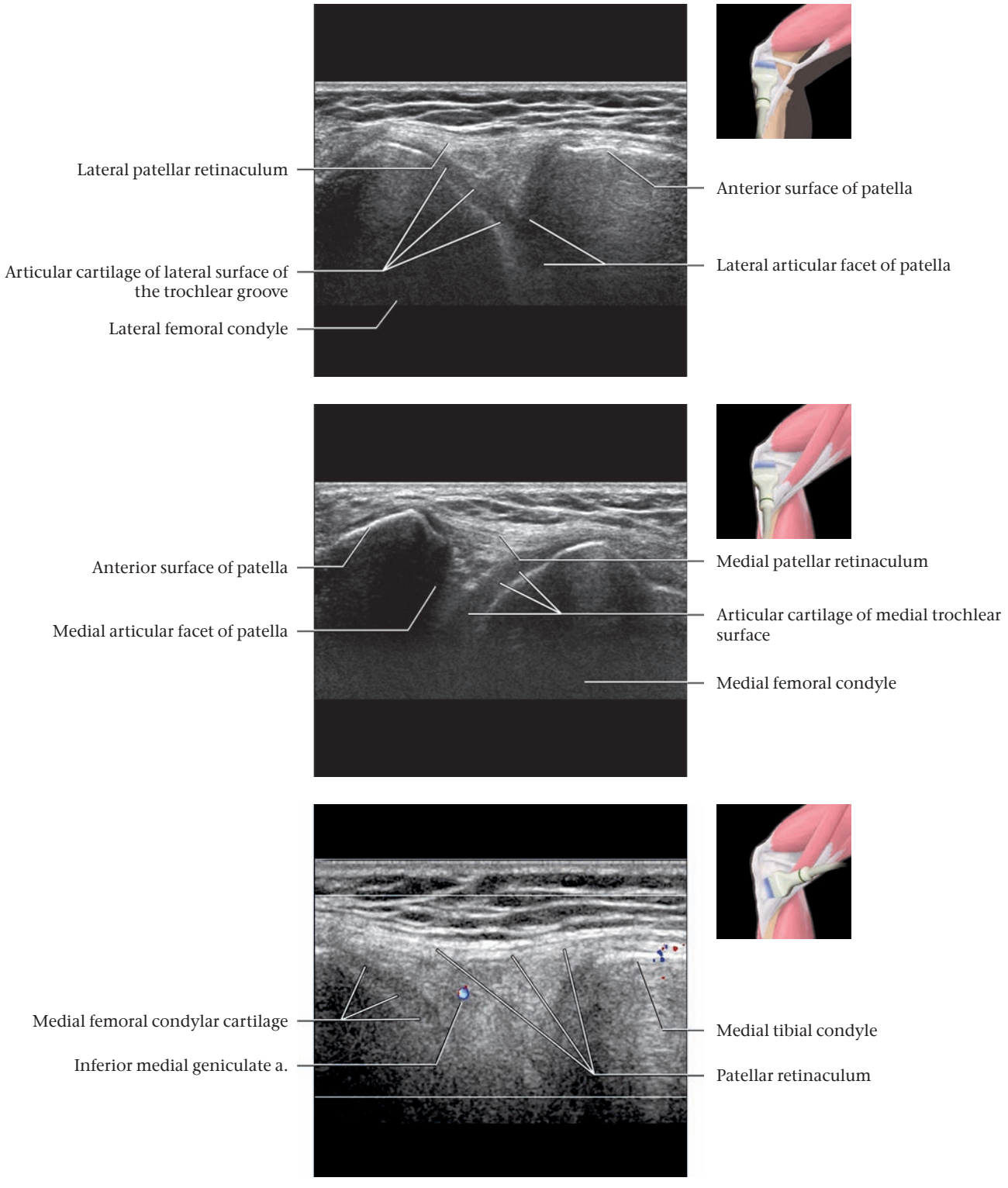
(Top) *Sagittal panoramic view shows the patellar tendon. Most of the fibers of the tendon are continuations of quadriceps tendon fibers.* ***(Middle)*** *Focused sagittal view of the apex of the patella shows quadriceps fibers running on the anterior surface of the patella, continuing distally as the patellar tendon. For this reason, many consider the patella a sesamoid bone. Also seen here are fibers originating from the apex of the patella itself.* ***(Bottom)*** *Focused sagittal scan shows the tibial tuberosity. The distal fibers of the patellar tendon are separated from the anterior surface of the tibial condyle by the infrapatellar bursa. A small amount of fluid (2-3 mm thick) may be normally present in this bursa.*

KNEE

EXTENSOR MECHANISM



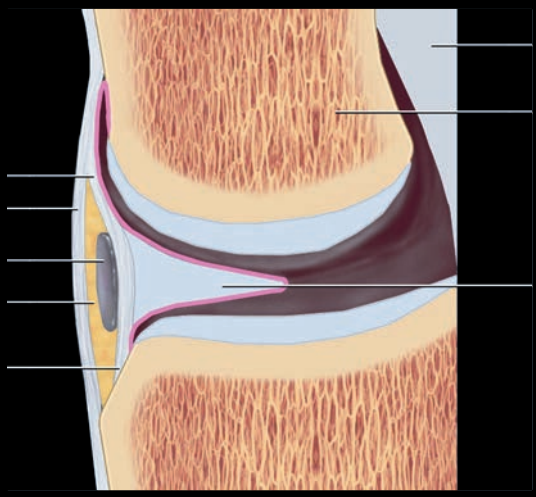
(Top) *Series of 3 transverse scans through the patellar tendon is shown. Proximally, fibers from the quadriceps tendon continue over the anterior patellar surface to contribute to the patellar tendon. On both sides, fibers from the medial and lateral patellar retinaculum also insert onto the patella and blend with the patellar tendon fibers.* ***(Middle)*** *At the midsubstance of the patellar tendon, the tendon assumes a flattened appearance. The fibers within the tendon can be seen as tiny hyperechoic dots. A disruption to the uniformity of these dots or a change in thickness (focal or general) of the patellar tendon suggests tendinosis.* ***(Bottom)*** *More inferiorly, a transverse scan shows the patellar tendon inserting onto the tibial tuberosity. The patellar tendon paratenon is seen as thin echogenic line on the anterior surface and side walls of the tendon. It becomes thickened in patellar paratenonitis. This is an infrequently encountered condition.*

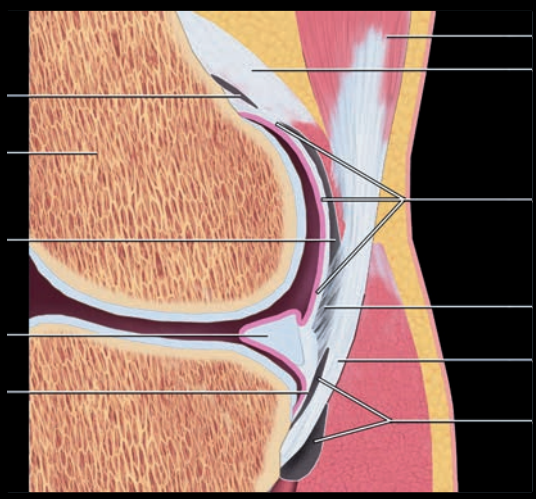


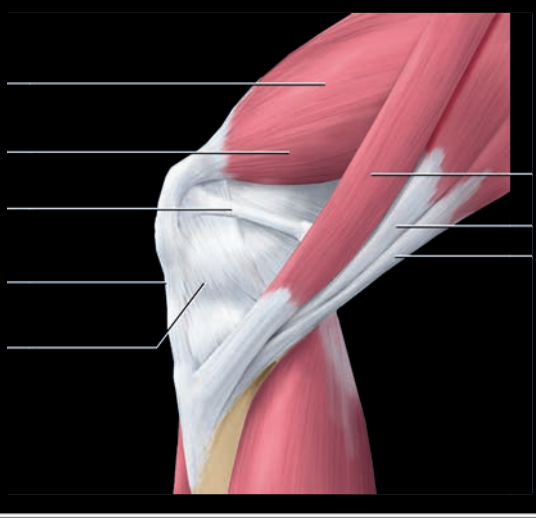
(Top) *Transverse scan at the lateral margin of the patella shows the articulation between the lateral patella and the lateral surface of the trochlear groove. This articular plane is steeper (closer to sagittal) than the medial side for mechanical advantage. As a result of the obliquity of the course of the patellar tendon with respect to the tibial axis, the patella is prone to lateral dislocation or subluxation. The steeper lateral articular plane helps prevents this.* ***(Middle)*** *Transverse scan at the medial margin of the patella shows the articulation between the patella and the medial surface of the trochlear groove, showing the patellar retinaculum as a thick structure.* ***(Bottom)*** *Sagittal color Doppler scan of the medial infrapatellar region shows the patellar retinaculum inserting onto the tibia. At this level, the retinaculum has fanned out, becoming much thinner.*

KNEE

MEDIAL KNEE

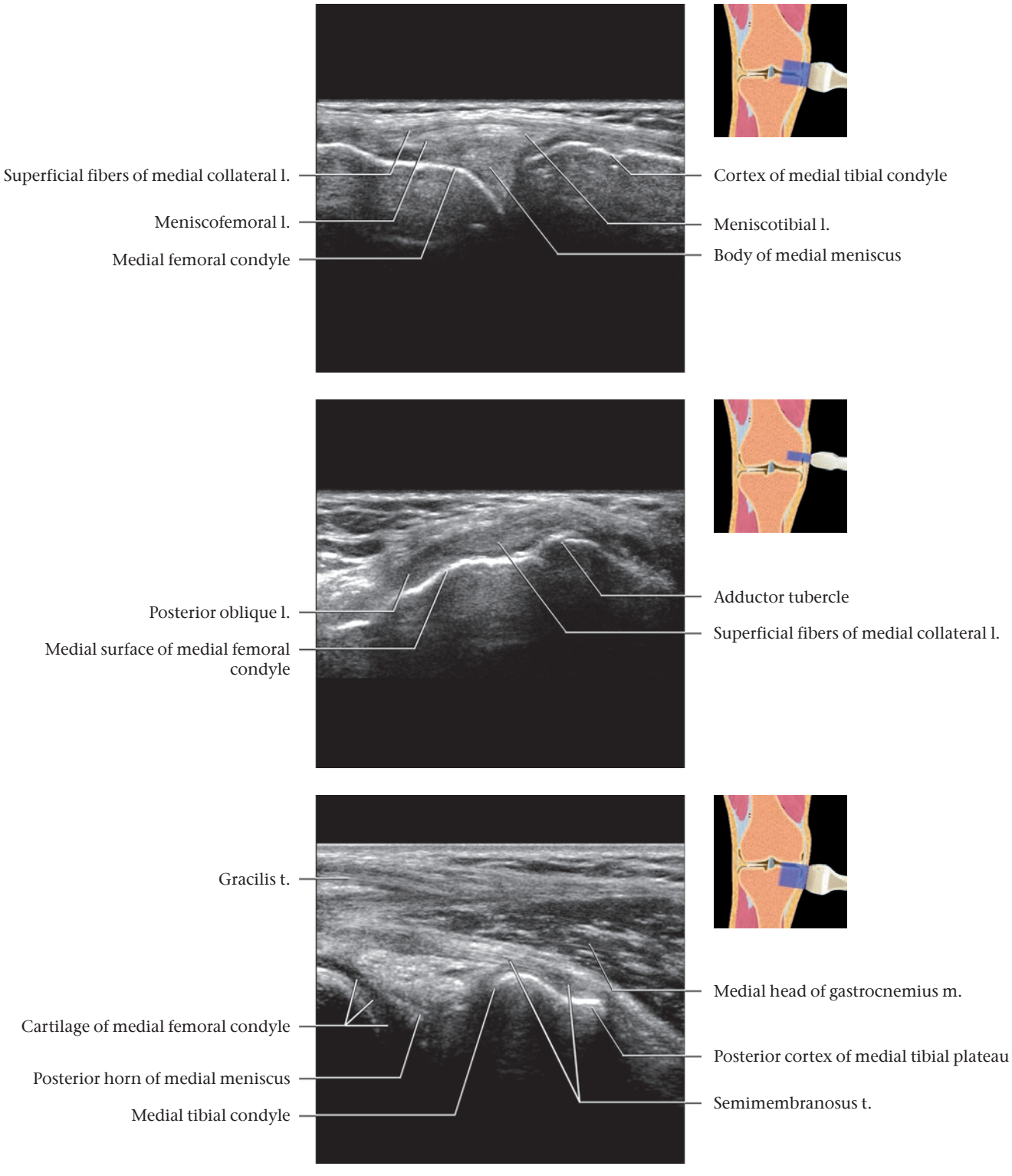






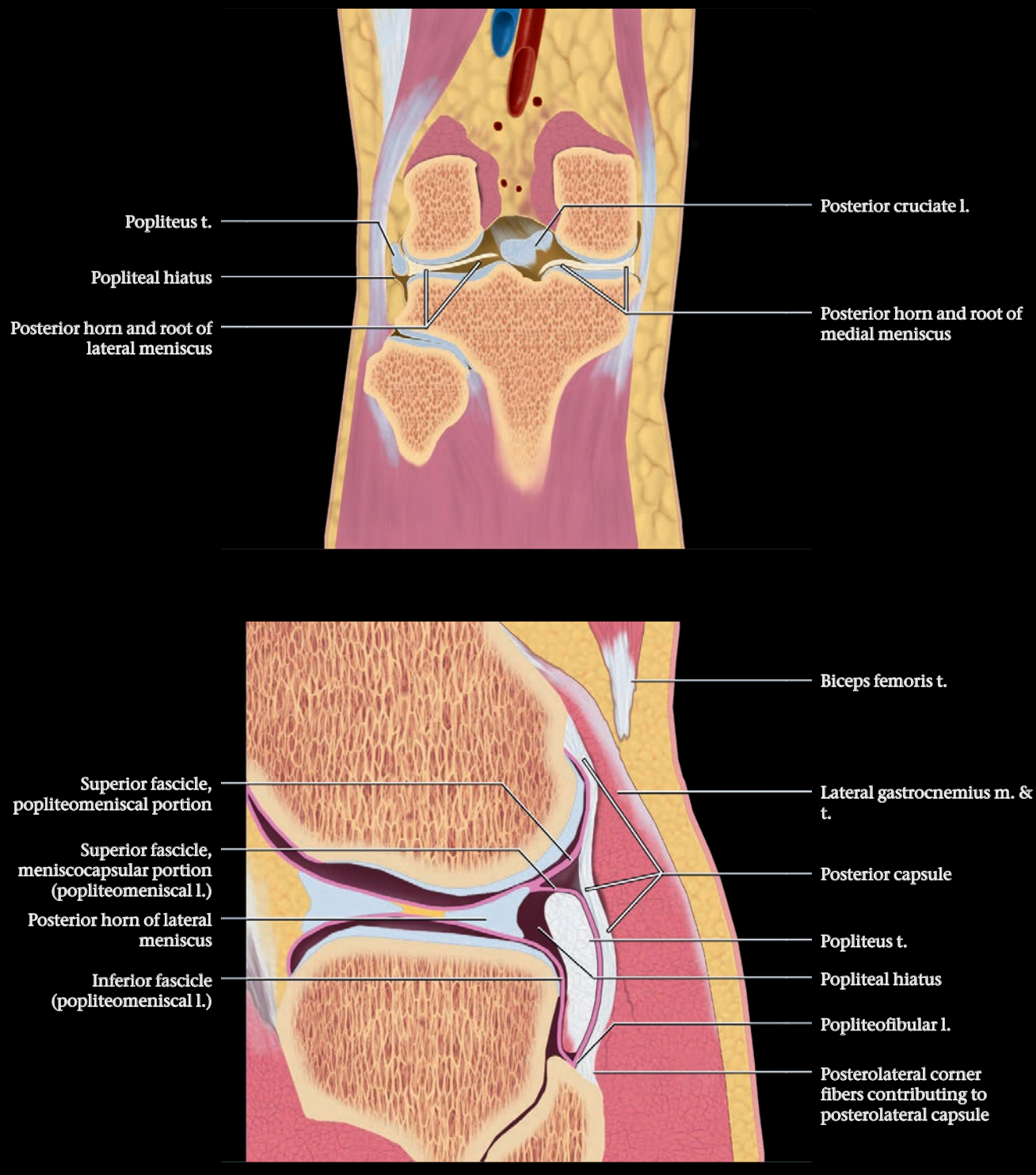
*(**Top**) Coronal graphic at midjoint shows superficial fibers extending from adductor tubercle to ~ 5 cm below the joint line. Deep fibers are shorter. The meniscotibial (coronary) ligament extends from the meniscus to the tibia adjacent to the joint line & the meniscofemoral ligament extends from the meniscus to the femur or superficial medial collateral ligament (MCL). (**Middle**) Sagittal graphic shows the far medial portion of posterior capsule. Superiorly, the capsule attaches to the cortex of the posterior femoral condyle and fuses with fibers of the medial gastrocnemius. (**Bottom**) Graphic shows the anteromedial attachment of pes anserinus tendons. The sartorius is the most anterior and superficial. The gracilis inserts directly adjacent and deep to the sartorius, and the semitendinosus inserts directly posterior and inferior to the gracilis. These tendons and their crural fascia comprise the superficial layer of the medial capsuloligamentous complex.*

MEDIAL KNEE



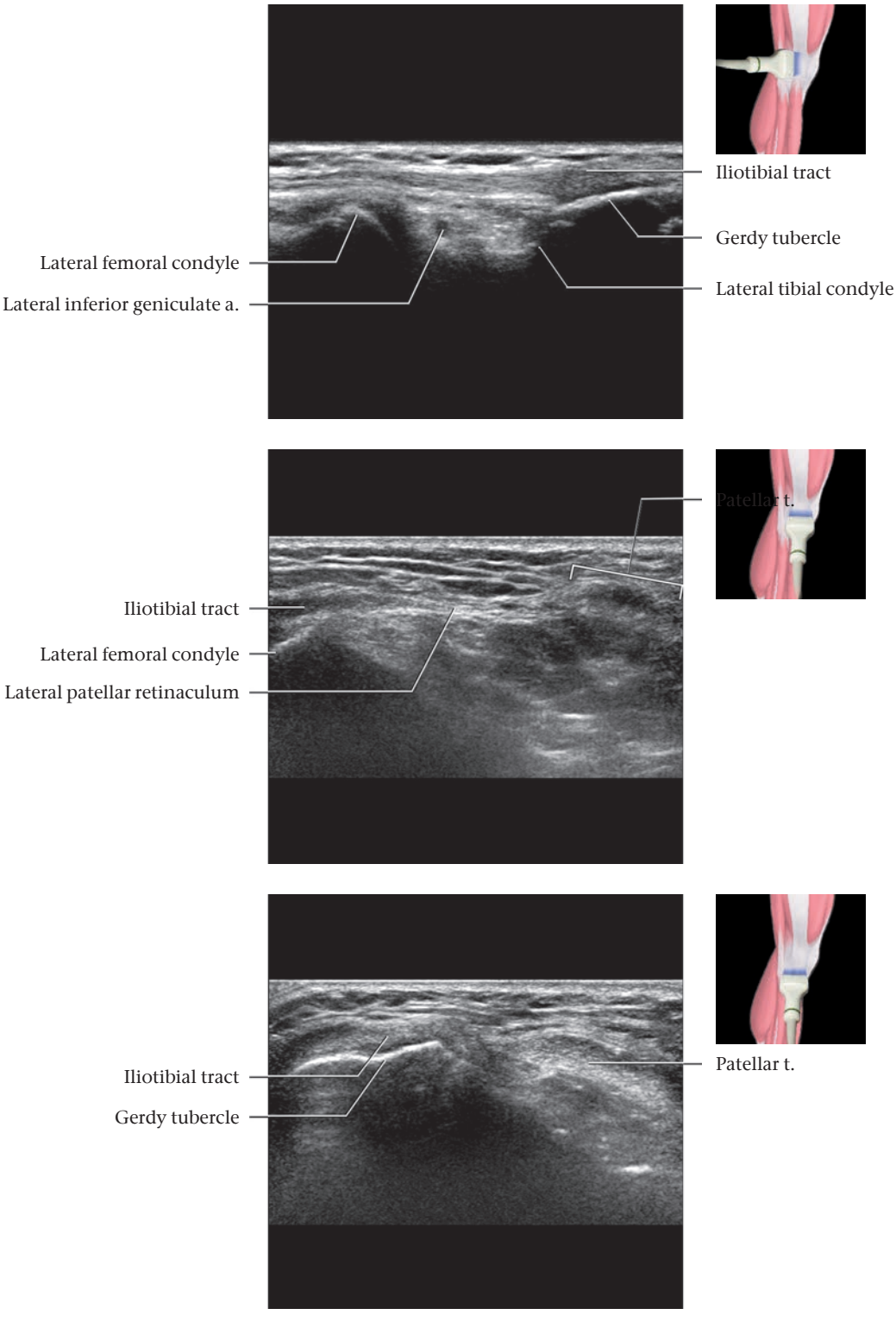
(Top) *Coronal scan shows the medial joint line. The medial collateral ligament is composed of 2 layers: Superficial and deep. The superficial fibers run from the medial femoral condyle to the tibial condyle 5 cm below the joint line. The deep layer consists of the meniscofemoral (femoral condyle to body of meniscus) and meniscotibial (body of meniscus to tibia just distal to joint line).* ***(Middle)*** *Transverse scan shows the medial condylar region. The superficial fibers of the medial collateral ligament arise just distal to the adductor tubercle. The popliteal oblique ligament arises adjacent to this and runs posterior to the posterior joint capsule.* ***(Bottom)*** *Sagittal scan shows the posteromedial joint line. The semimembranosus tendon inserts onto the posterior surface of the medial tibial condyle, just below the joint margin. Only the outer part of the meniscus is visible.*

LATERAL KNEE



*(**Top**) Coronal graphic shows the roots of the posterior horns of both the medial and lateral menisci. The popliteus tendon courses through the hiatus adjacent to the body/posterior horn of the lateral meniscus. (**Bottom**) Sagittal graphic of lateral part of posterior capsule shows that it is intimately attached to the lateral gastrocnemius muscle. The popliteus tendon is intraarticular but extrasynovial and is attached to the capsule. Fibers from the posterolateral corner and arcuate ligament originating from the fibular head contribute to the lateral portion of the posterior capsule.*

LATERAL KNEE

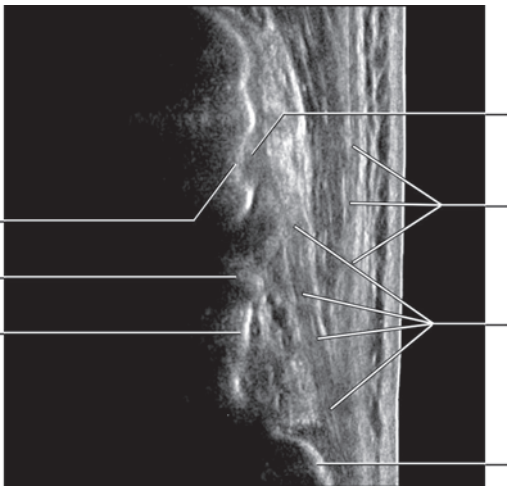


(Top) *Oblique sagittal scan shows the lateral aspect of the joint line using Gerdy tubercle as a landmark. The iliotibial tract is shown here, passing over the edge of the lateral femoral condyle (where it is subject to impingement [iliotibial tract syndrome]) before inserting on the Gerdy tubercle on the anterior surface of the lateral tibial condyle.* ***(Middle)*** *Transverse scan of the anterolateral knee at the level of the femoral condyle shows that the iliotibial tract and the patellar tendon are connected by fibers of the lateral patellar retinaculum.* ***(Bottom)*** *More inferiorly, the 2 tendons have moved closer to each other. This transverse scan shows insertion of the iliotibial tract onto the Gerdy tubercle. The patellar tendon is also approaching its tibial insertion.*

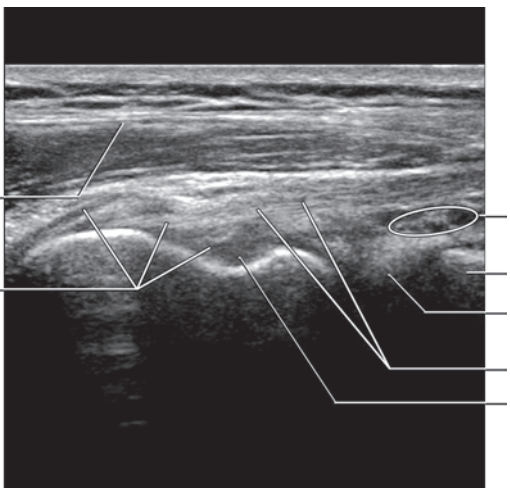
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LATERAL KNEE

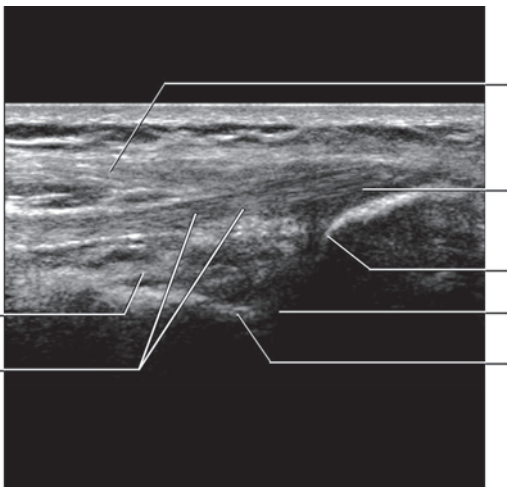






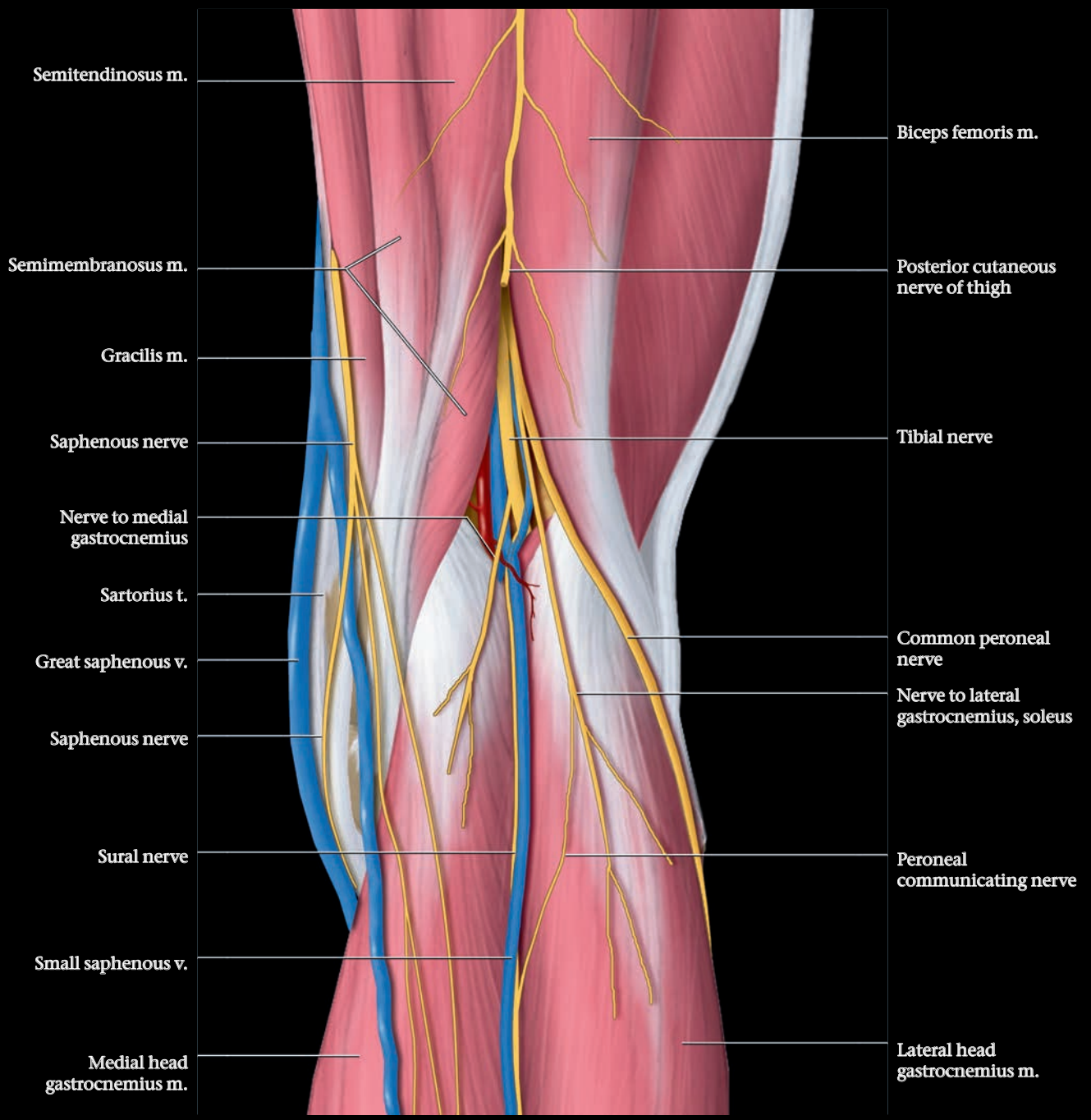






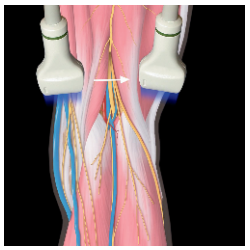
(Top) *Coronal panoramic scan shows the lateral collateral complex. The biceps femoris muscle is the dominant muscle on this side of the knee. It runs from the ischial tuberosity laterally and inferiorly to insert onto the lateral aspect of the head of the fibula.* ***(Middle)*** *Coronal scan of the lateral femoral condyle shows the insertion of the fibular collateral ligament. Just under this insertion is the groove for the popliteal tendon. The fibular collateral ligament is cord-like compared to the superficial component of the lateral collateral ligament, which is a flatter strap.* ***(Bottom)*** *The fibular collateral ligament inserts onto the lateral wall of the head of the fibula. The tendon of the biceps femoris inserts at and around the apex of the fibular head.*

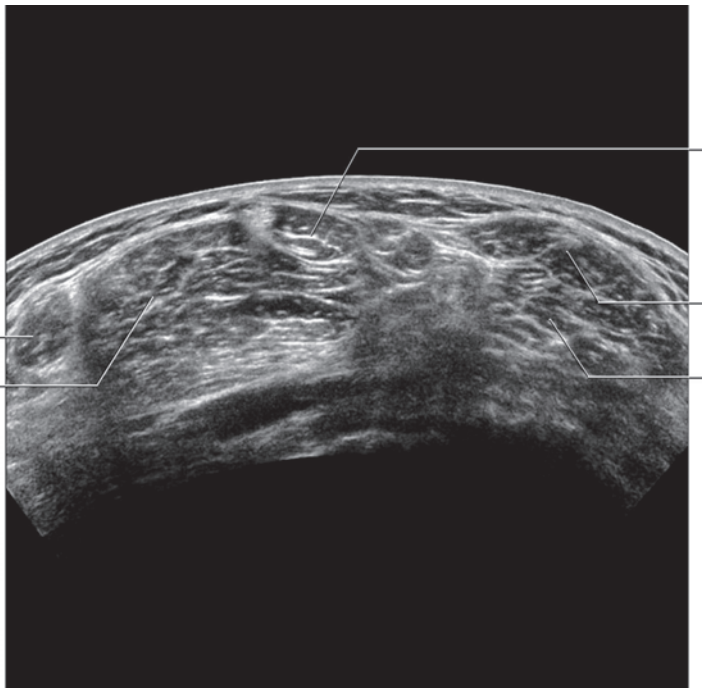
POSTERIOR KNEE

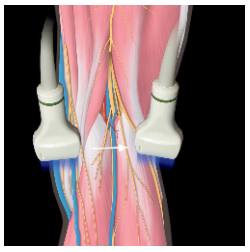


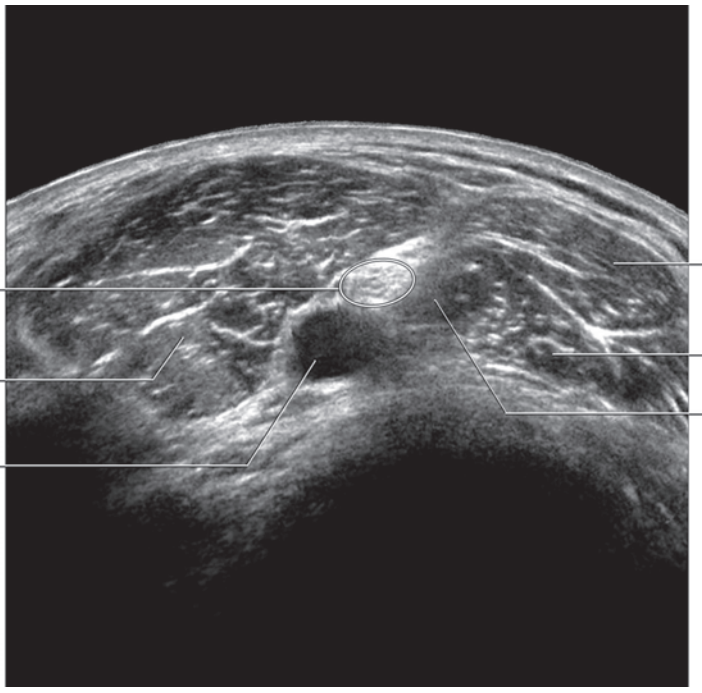
Graphic shows the superficial posterior muscles and nerves. The popliteal fossa is a diamond-shaped fossa bordered superiorly by the hamstring muscles and inferiorly by the head of the gastrocnemius muscle. Superiorly, the medial margin is represented by the semimembranosus and semitendinosus muscles, and laterally by the biceps femoris muscle. Inferiorly, the medial and lateral borders are the medial and lateral heads of the gastrocnemius muscle. This fossa contains the popliteal vessels, the sciatic nerve, and its branches. Note that the common peroneal nerve is part of the deeper nerve system, but it travels more superficially, following the posterior biceps femoris muscle and tendon until it wraps around the fibular neck.

POSTERIOR KNEE



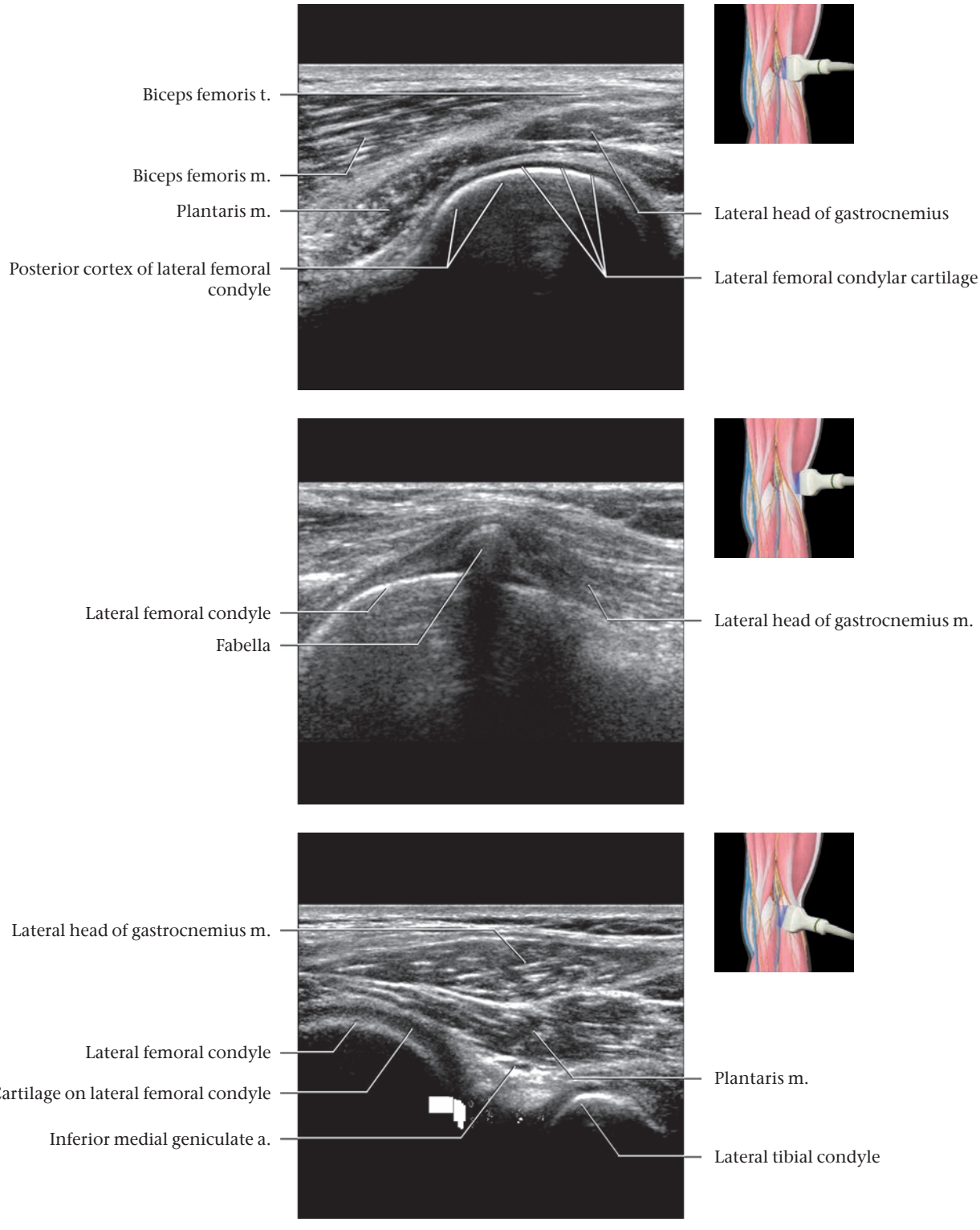






(Top) *Panoramic transverse scan of the posterior knee shows the upper popliteal fossa. At this level, the hamstring muscles form the superior boundaries (medial and lateral) of the popliteal fossa. The semimembranosus and semitendinosus muscles form the medial margin, while the biceps femoris muscle forms the lateral margin.* ***(Bottom)*** *Panoramic view of the posterior knee shows the lower aspect of the popliteal fossa. At this level, the boundaries of the popliteal fossa are the heads of the gastrocnemius muscle, the lateral head of gastrocnemius being the lateral margin and the medial head the medial margin. The popliteal vessels are a continuation of the superficial femoral vessels after they have emerged through the adductor hiatus.*

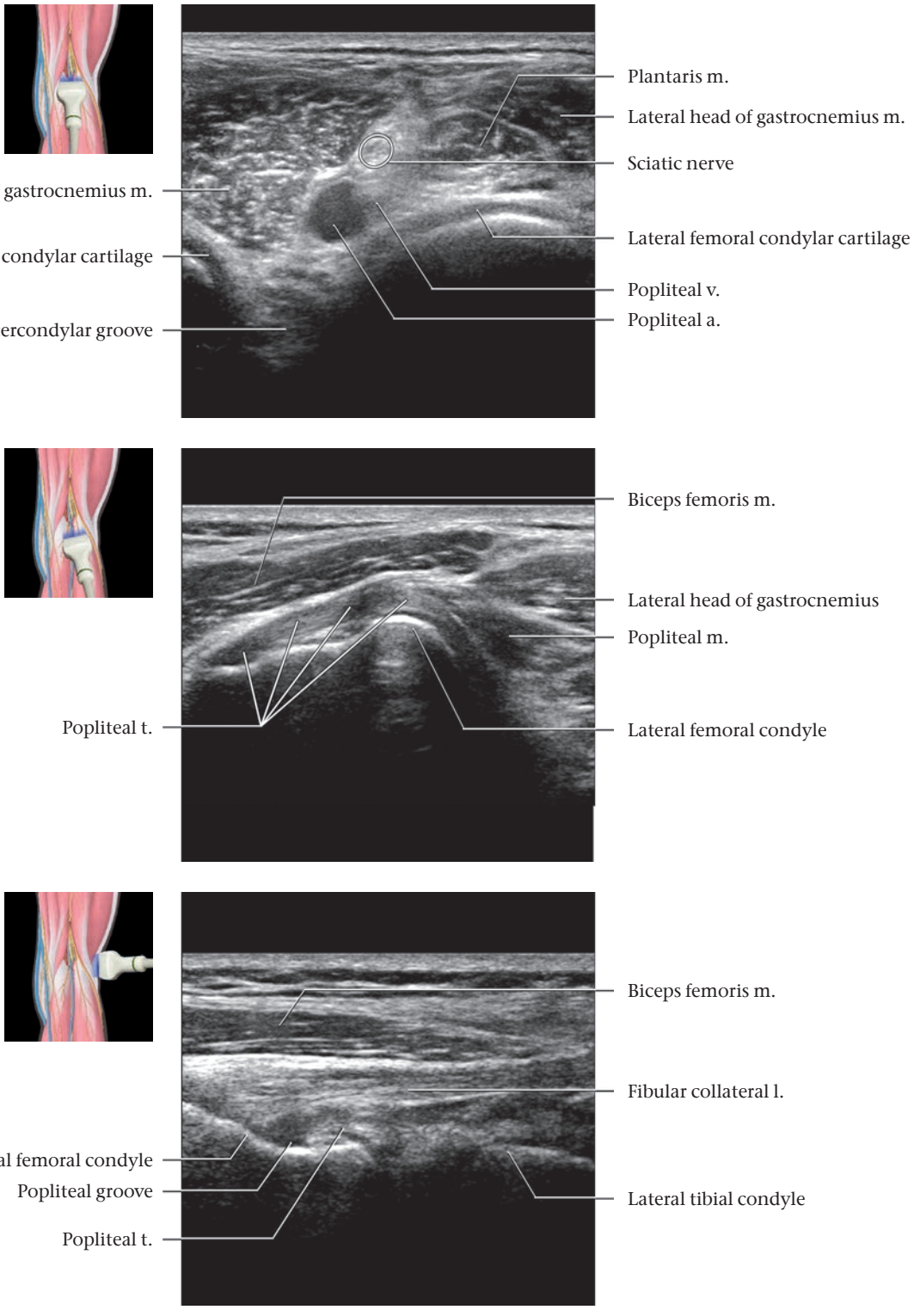
POSTERIOR KNEE



(Top) *Sagittal scan shows the lateral femoral condyle. The plantaris muscle originates slightly more superior and medial to the lateral head of the gastrocnemius. The plantaris runs inferomedially across the thigh to lie on the medial side of the Achilles tendon. More superficially, the bicipital tendon runs laterally toward its fibular head insertion.* ***(Middle)*** *A more lateral sagittal view shows the sesamoid bone within the lateral head of the gastrocnemius muscle, the fabella.* ***(Bottom)*** *A more inferior oblique scan shows both the plantaris and lateral heads of the gastrocnemius muscle running over the posterior surface of the knee joint. Further distally, the plantaris muscle becomes a thin tendon and is difficult to discern until it reaches the medial side of the Achilles tendon in the distal calf.*

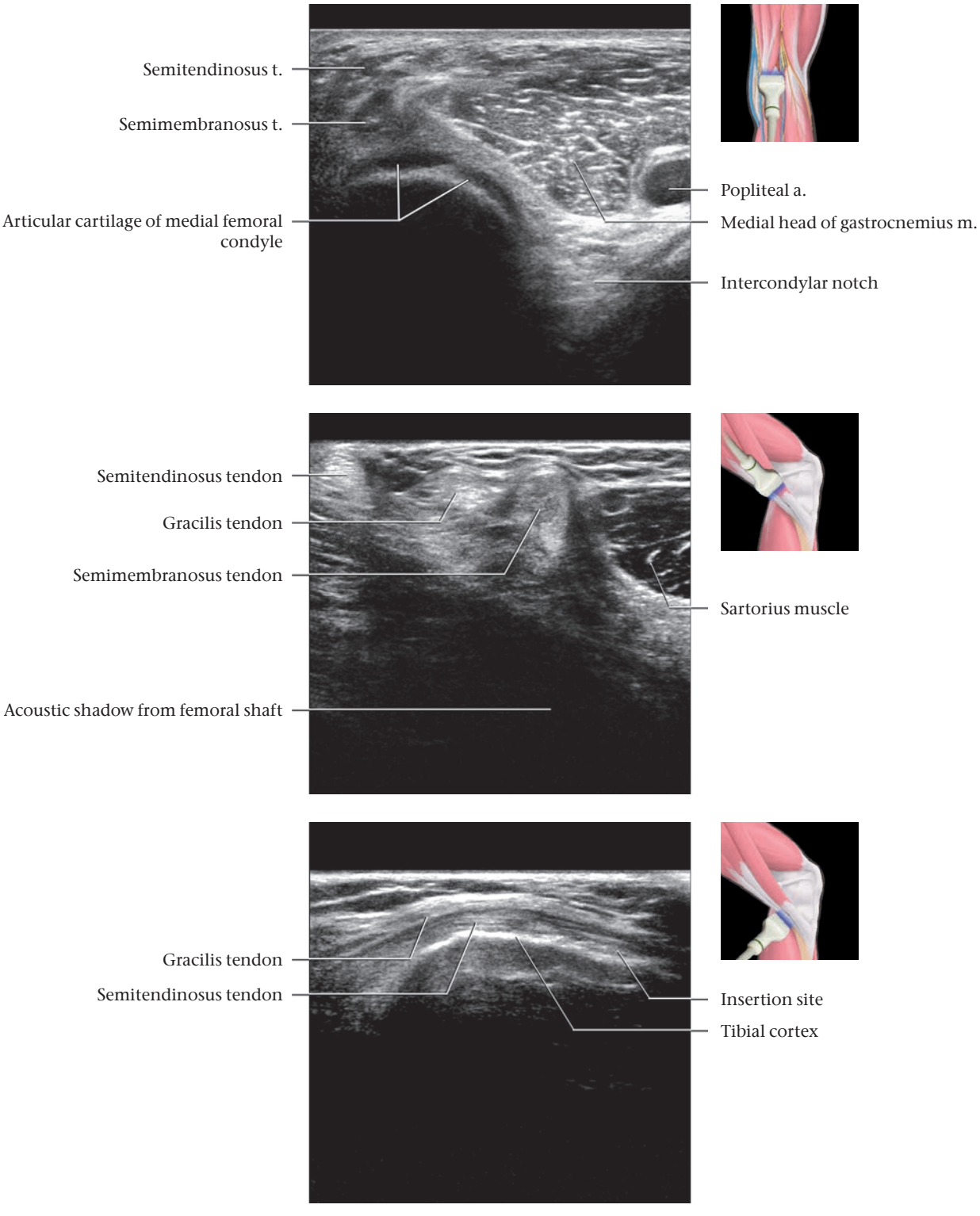
KNEE

POSTERIOR KNEE



(Top) *Transverse scan shows the posterolateral aspect of the knee joint at the level of the inferior popliteal fossa. The sciatic nerve is the largest nerve in the body. In cross section, nerve fibrils are seen as hypoechoic dots separated by hyperechoic perineurium.* ***(Middle)*** *Scanning more laterally and inferiorly, the popliteal muscle and its tendon can be demonstrated. The popliteal tendon originates from the proximal posterior tibial surface and runs superolaterally under the lateral head of the gastrocnemius muscle to insert onto the lateral cortex of the lateral femoral condyle.* ***(Bottom)*** *Coronal scan shows the popliteal groove on the lateral femoral condyle and the popliteal tendon entering this groove as it heads toward its insertion.*

POSTERIOR KNEE



(Top) *Transverse scan shows the posteromedial knee at the level of the femoral condyles. The semimembranosus tendon can be seen running medial to the medial head of the gastrocnemius muscle and deep to the semitendinosus tendon. The semimembranosus tendon will continue inferiorly to its posterior tibial insertion, whereas the semitendinosus will be joined by others to insert on the anteromedial surface of the tibia.* ***(Middle)*** *More superiorly, transverse scan of the posteromedial aspect of the supracondylar region shows the medial tendons and muscles. Three of these, the sartorius, gracilis, and semitendinosus, will continue together inferiorly and insert adjacent to each other as the pes anserine on the anteromedial aspect of the proximal tibial shaft.* ***(Bottom)*** *Oblique transverse scan along the course of the pes anserine tendons shows their insertion on the anteromedial tibial cortex.*

LEG MUSCLES

TERMINOLOGY

Abbreviations

- Artery (a.), ligament (l.), muscle (m.), vein (v.), tendon (t.)

GROSS ANATOMY

Osseous Anatomy

- **Tibia**
  - Proximal tibiofibular joint
    - Head of fibula and lateral condyle tibia joined by synovial-lined fibrous capsule
    - May communicate with knee joint (10%)
    - Posterolaterally located
    - Synovial joint, so can be affected by any synovial inflammatory process
  - Anterolateral tibia: Origin of anterior muscles of leg
  - Anterior border (shin): Sharp ridge running from tibial tuberosity proximally to anterior margin of medial malleolus
  - Medial tibial surface
    - Wide and flat
    - Proximally, covered by pes anserinus
    - Remainder is subcutaneous
  - Medial border of tibia: Saphenous nerve and great saphenous vein run along it
  - Posterior tibia: Origin of deep posterior muscles of leg
  - Lateral border of tibia: Ridge for attachment of interosseous membrane
  - Medial malleolus: 2 colliculi, anterior longer than posterior
  - Distal tibiofibular joint
    - Fibula articulates with tibia at fibular notch; joined by interosseous ligament
    - Strengthened by anterior and posterior tibiofibular ligaments
    - Posterolaterally located
- **Fibula**
  - Anterior fibula
    - Origin of lateral muscles of leg
  - Medial fibula
    - Origin of deep posterior muscles of leg
  - Posterolateral fibula
    - Origin of posterior muscles of leg
  - Lateral malleolus: 1 cm longer than medial malleolus

Interosseous Membrane

- Stretches across interval between tibia and fibula
- Greatly extends surface for origin of muscles
- Strong, oblique fibers run downward and laterally from tibia to fibula
- In upper part, below lateral condyle of tibia, there is an opening for passage of anterior tibial vessels
- Distally, an opening allows passage of perforating branch of peroneal artery
- Tibialis posterior and flexor hallucis longus take partial origin from back of membrane
- Tibialis anterior, long extensors of toes, and peroneus tertius take partial origin from front of membrane

Muscles of Leg

- Compartments separated by deep fascia, which give partial origin to several muscles
- **Posterior compartment: Superficial muscles**
  - **Gastrocnemius**
    - Origin: Medial from posterior femoral metaphysis; lateral from posterior edge of lateral epicondyle
    - Heads separated from posterior capsule by a bursa
    - 2 heads unite to form main bulk of muscle
    - Join in a thin aponeurotic tendon near midleg
    - Joins soleus aponeurosis to form Achilles tendon; concave in cross section; musculotendinous junction 5 cm above calcaneal insertion
    - Nerve supply: Tibial nerve
    - Action: Plantar flexor of ankle and flexor of knee
  - **Plantaris**
    - Origin: Superior and medial to lateral head of gastrocnemius origin, as well as from oblique popliteal ligament
    - Continues deep to lateral head of gastrocnemius
    - Myotendinous junction at level of origin of soleus (muscle is 5-10 cm long)
    - Tendon then lies between medial head gastrocnemius and soleus
    - Follows medial side of Achilles to insert either anteromedially on Achilles or on calcaneus
    - Plantaris absent in 7-10% of general population
    - Nerve supply: Tibial nerve
    - Action: Acts with gastrocnemius
  - **Soleus**
    - Origin: Extensive, from back of fibular head and upper 1/3 of posterior surface of shaft of fibula, from soleal line and middle 1/3 of medial border of tibia, and from tendinous arch joining these across popliteal vessels
    - Flat, thick, powerful muscle that ends in strong tendon
    - Joins with tendon of gastrocnemius to form Achilles tendon
    - Nerve supply: Tibial nerve
    - Action: Stabilizes ankle in standing, plantarflexes ankle
    - Accessory soleus: Rare variant, arises from anterior surface of soleus or from fibula and soleal line of tibia; inserts into Achilles or onto calcaneus anteromedially to Achilles; presents as mass
- **Posterior compartment: Deep muscles**
  - **Popliteus**
    - Origin: Tendon from popliteal groove of lateral femoral condyle
    - Passes through popliteal hiatus posteriorly and medially, pierces posterior capsule of knee
    - Muscle fibers directed medially and downward to insert on posterior surface of tibia above soleal line
    - Nerve supply: Tibial nerve
    - Action: Flexes knee and medially rotates tibia with respect to femur at onset of flexion (unlocking extension "screwing home" mechanism)
  - **Tibialis posterior**
    - Origin: Interosseous membrane and adjoining parts of posterior surfaces of tibia and fibula
    - Superior end bifid; anterior tibial vessels pass forward between the 2 attachments
    - Distally it inclines medially, under flexor digitorum longus
    - Grooves and curves around medial malleolus
    - Nerve supply: Tibial nerve
    - Action: Plantarflexes and inverts foot
  - **Flexor digitorum longus**

- Origin: Posterior surface of tibia, below popliteus, and medial to vertical ridge
- Crosses superficial to distal part of tibialis posterior
- Tendon grooves lower end of tibia lateral to that of the tibialis posterior, passes around medial malleolus to foot
- Nerve supply: Tibial nerve
- Action: Flexes interphalangeal and metatarsophalangeal joints of lateral 4 toes; plantarflexes and inverts foot

◦ **Flexor hallucis longus**
- Origin: Posterior surface of fibula, below origin of soleus
- Passes medially, descends down posterior to midtibia
- Associated with os trigonum posterior to talus
- Tendon occupies deep groove on posterior surface of talus, passes around medial malleolus, under sustentaculum tali, to great toe
- Nerve supply: Tibial nerves
- Action: Flexes interphalangeal and metatarsophalangeal joints of great toe; plantarflexes foot

· **Lateral compartment**

◦ Peroneals separated from extensors by anterior intermuscular septum and from posterior muscles by posterior septum

◦ **Peroneus longus**
- Origin: Upper 2/3 lateral surface of fibula and intermuscular septa and adjacent muscular fascia
- Becomes tendinous a few cm above lateral malleolus
- Curves forward behind lateral malleolus, posterior to peroneus brevis
- Nerve supply: Superficial peroneal
- Action: Everts foot and secondarily plantarflexes foot

◦ **Peroneus brevis**
- Origin: Lower 2/3 lateral surface of fibula and intermuscular septa and adjacent muscular fascia
- Muscle is medial to peroneus longus at origin but overlaps peroneus longus in middle 1/3
- Tendon curves forward behind lateral malleolus, in front of peroneus longus tendon
- Nerve supply: Superficial peroneal
- Action: Everts foot and secondarily plantarflexes foot

◦ Synovial sheath for peroneals begins 5 cm above tip of lateral malleolus and envelops both tendons; divides into 2 sheaths at level of calcaneus

◦ **Peroneus quartus**
- Accessory muscle with prevalence of 10%
- Originates from distal leg, frequently from peroneal muscles, with variable insertion sites at foot
- At level of malleolus, located medial or posterior to both peroneal tendons

◦ **Peroneus digiti minimi**
- Accessory with prevalence of 15-36%
- Extends from peroneus brevis muscle around medial malleolus to foot
- Tiny tendinous slip

· **Anterior compartment**

◦ **Tibialis anterior**
- Origin: Upper 1/2 of lateral surface of tibia and interosseous membrane
- Tendon originates in distal 1/3; passes deep to retinaculum
- Nerve supply: Deep peroneal and recurrent genicular
- Action: Dorsiflexor and invertor of foot

◦ **Extensor digitorum longus**
- Origin: From upper 3/4 of anterior surface fibula
- Descends behind extensor retinacula to ankle
- Nerve supply: Deep peroneal
- Action: Extends interphalangeal and metatarsophalangeal joints of lateral 4 toes, dorsiflexes foot

◦ **Peroneus tertius**
- Small, not always present
- Origin: Continuous with extensor digitorum longus, arising from distal 1/4 of anterior surface of fibula and interosseous membrane
- Inserts into dorsal surface at base of 5th metatarsal
- Nerve supply: Deep peroneal
- Action: Dorsiflexes ankle and everts foot

◦ **Extensor hallucis**
- Thin muscle hidden between tibialis anterior and extensor digitorum longus
- Origin: Middle 1/2 of anterior surface of fibula and interosseous membrane
- Tendon passes deep to retinacula to great toe
- Nerve supply: Deep peroneal
- Action: Extends phalanges of great toe and dorsiflexes foot

ANATOMY IMAGING ISSUES

Imaging Recommendations

· US

◦ Owing to its smaller size, compared to thigh (less depth to penetrate), leg muscles and vessels are well demonstrated by ultrasound throughout their course

◦ Relationship of different structures in posterior compartment tends to change along their courses
- If in doubt, start from ankle level and trace structures proximally

Imaging Sweet Spots

· Deep structures of posterior compartment, such as peroneal vessels and tibialis posterior muscle, may be difficult to visualize in very muscular patients

◦ Structures can be interrogated by scanning from anterior through anterior compartment and gap between tibia and fibula

· One of the most common reasons to image the calf is for suspected muscle tear

◦ Most common site of muscle tear is at distal myofascial junction of medial belly of gastrocnemius

◦ Look carefully for preservation of arrowhead appearance of myofascial junction at this location

◦ With plantaris tendon tear, this junction is intact, and there is more extensive hemorrhage deep to medial belly of gastrocnemius

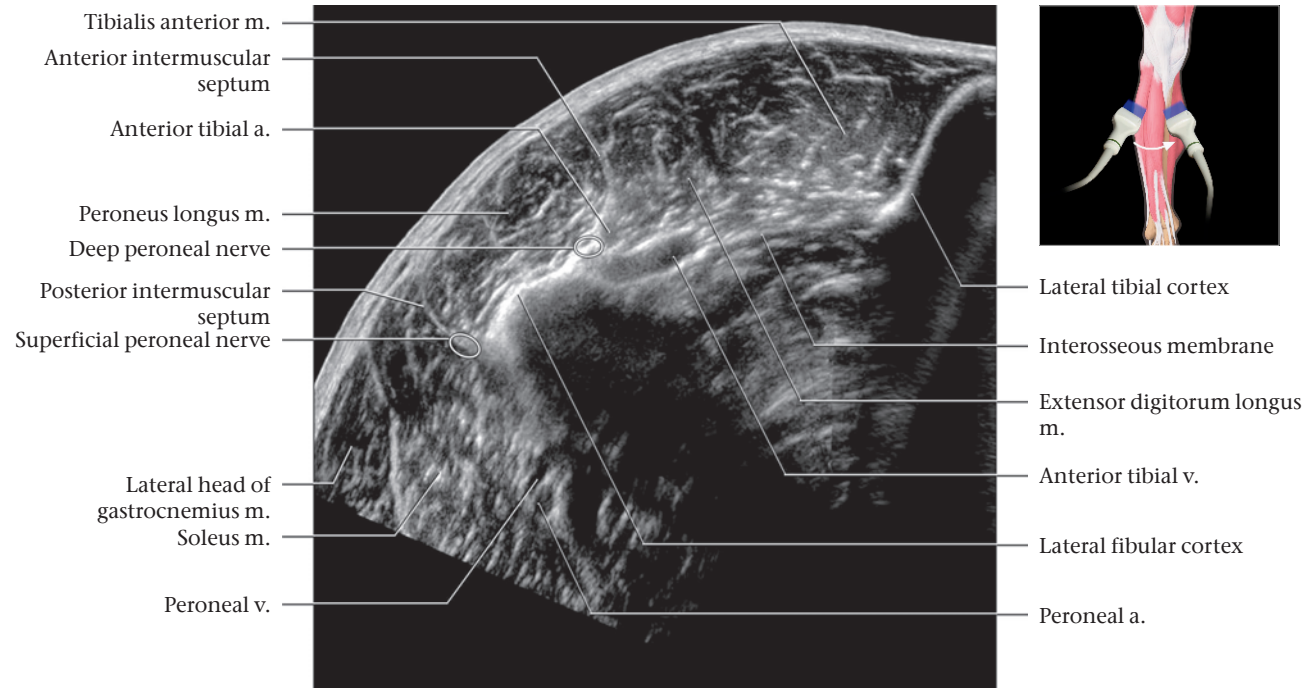
LEG MUSCLES

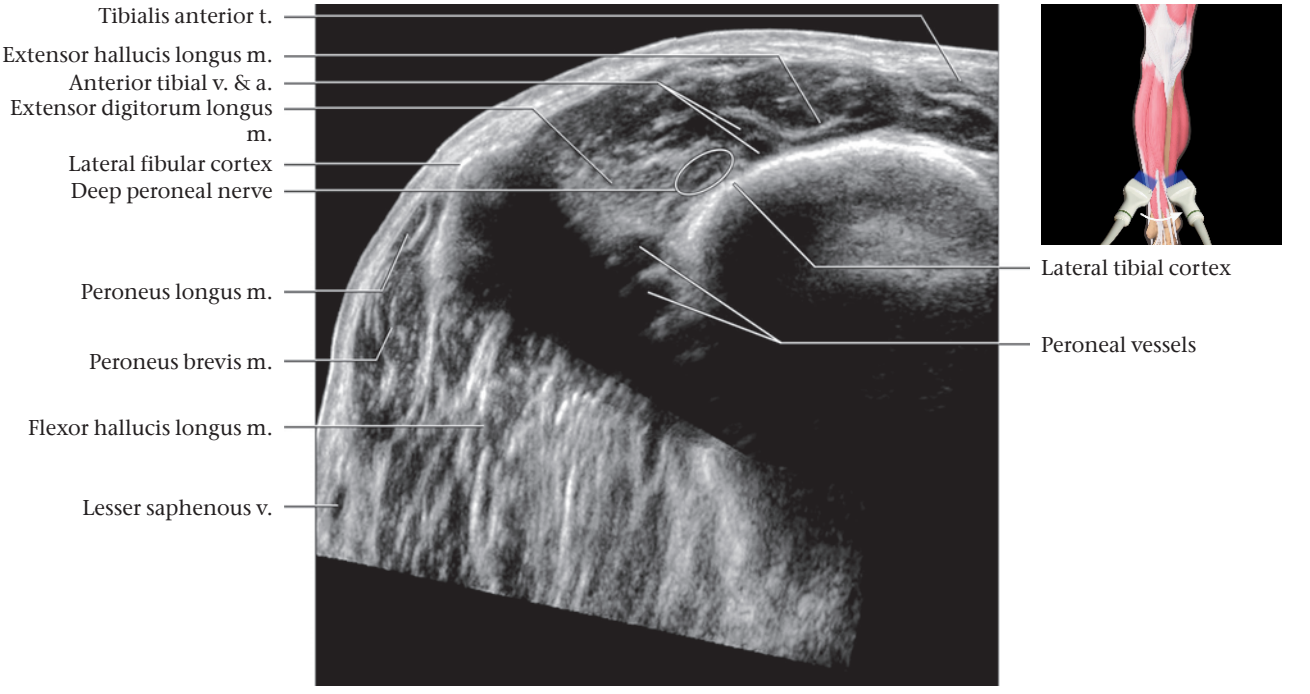
ANTEROLATERAL LEG



Graphic shows the anterior leg muscles. Note that nearly the entire anteromedial tibia is bare of muscle. Thus, it is poorly vascularized, resulting in slow fracture healing. The tibialis anterior has an extensive origin from both tibia and interosseous membrane and is the most substantial muscle of the anterior compartment. The extensor digitorum longus originates from the fibula. The extensor hallucis longus originates between the 2, from the fibula and the interosseous membrane. These 3 muscles retain the same orientation as they become tendinous anterior to the ankle. The mnemonic "Tom, Harry, & Dick" applies to the tendon order, from medial to lateral (tibialis anterior, extensor hallucis longus, extensor digitorum).

PANORAMIC ANTEROLATERAL LEG

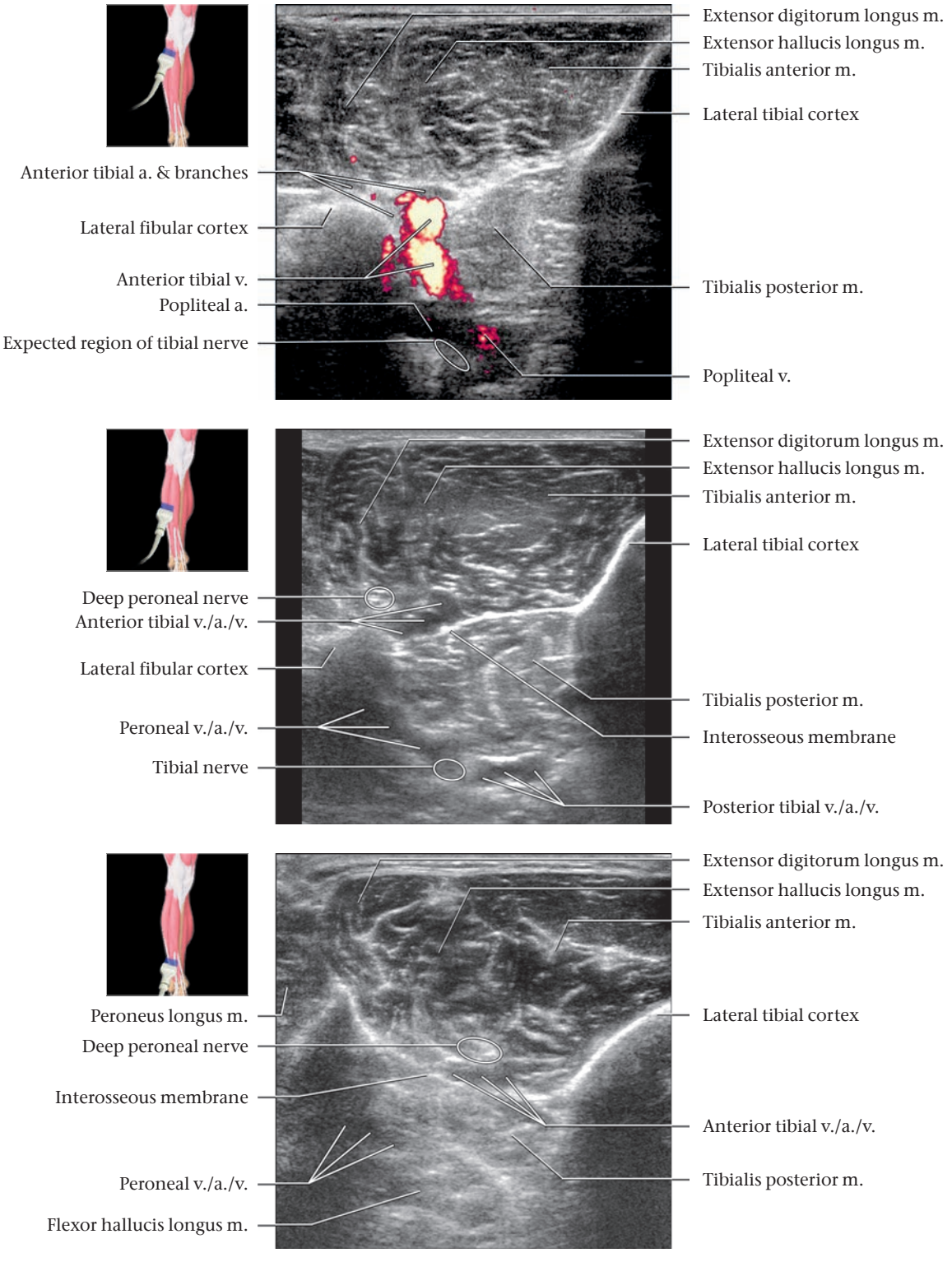




(Top) *Transverse panoramic view shows the anterior and lateral compartments of the upper leg. The crural compartments are divided by the tibia and the 2 intermuscular septa (anterior and posterior) into the anterior (extensor), lateral (peroneal), and posterior (flexor) compartments. The intermuscular septum separates the anterior from the posterior compartments.* ***(Bottom)*** *Transverse panoramic view shows the anterior and lateral compartments of the inferior leg. All muscles are smaller in caliber compared to those seen superiorly. An interosseous gap is still present between the the tibia and fibula, but ultrasound interrogation through this gap is no longer possible and the interosseous membrane cannot be demonstrated.*

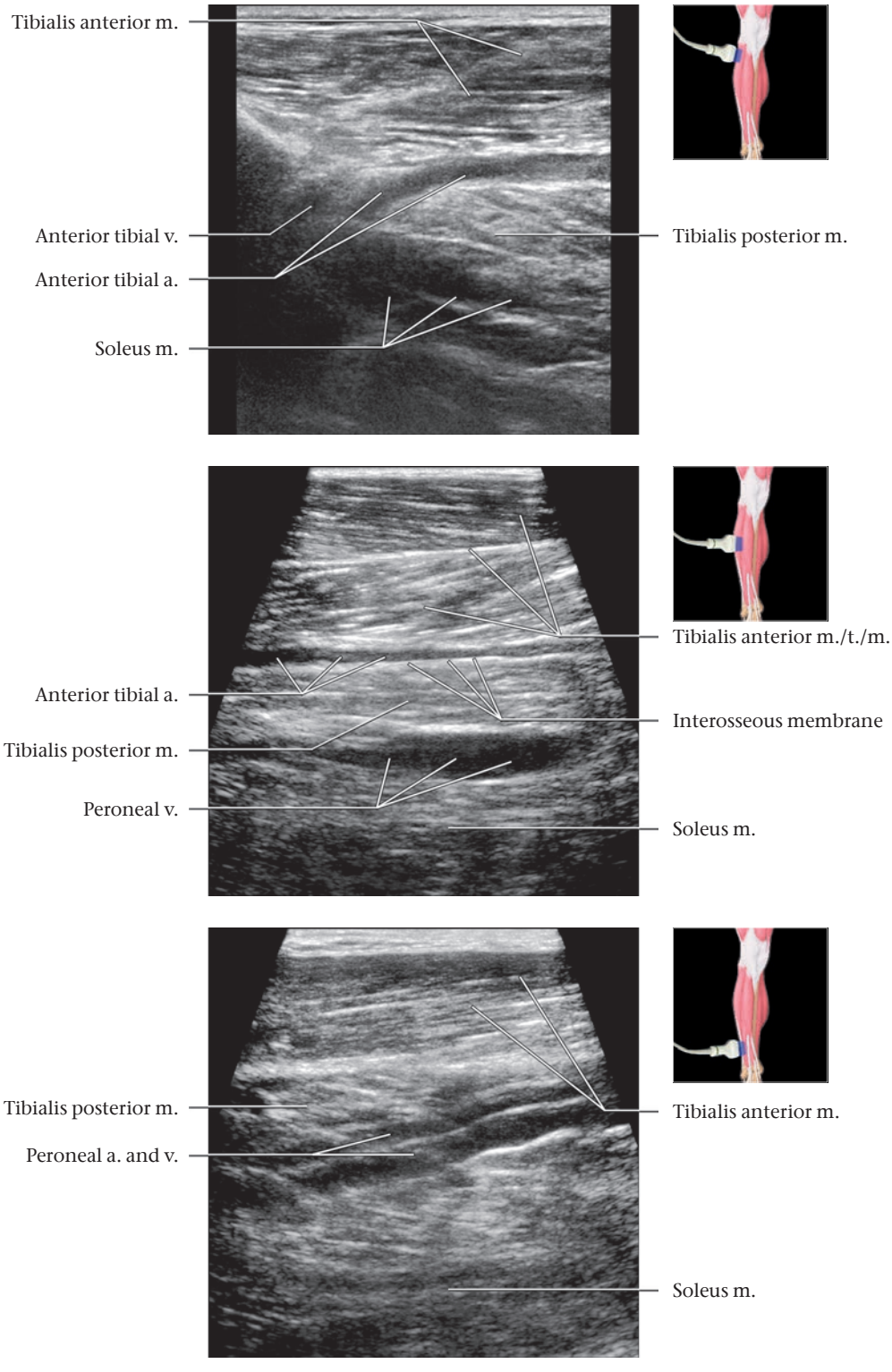
LEG MUSCLES

ANTERIOR COMPARTMENT



(Top) *Transverse color Doppler scan shows the anterior compartment at the upper leg level slightly below the proximal tibiofibular joint. At this level (above the superior margin of the interosseous membrane), the anterior tibial artery and vein (branches of the popliteal artery and vein) run anteriorly to supply the anterior compartment.* ***(Middle)*** *Transverse scan shows the anterior compartment at a slightly lower level. The tibialis anterior, extensor hallucis longus, and extensor digitorum longus muscles form the muscular component of this compartment. The deep peroneal nerve has penetrated laterally to supply this compartment. The anterior tibial vessels run on the surface of the interosseous membrane.* ***(Bottom)*** *Transverse scan more inferiorly shows a decrease in size of the extensor muscles and gradual migration of nerve and vessels more medially and superficially.*

ANTERIOR COMPARTMENT

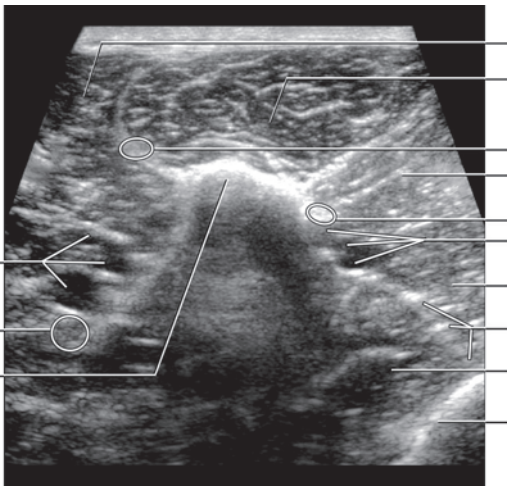


(Top) *Sagittal scan shows the anterior compartment at the upper leg level. The anterior tibial vessels pass above the superior margin of the interosseous membrane to enter the anterior compartment and supply the extensor muscles.* ***(Middle)*** *Sagittal scan of the anterior and posterior compartments at the midleg level shows that the interosseous gap between the tibia and fibula can be used as a window to interrogate the deep posterior structures.* ***(Bottom)*** *Sagittal scan shows the anterior compartment at a lower level. Within the posterior compartment, the peroneal vessels run anteriorly and just below the inferior margin of the interosseous membrane.*

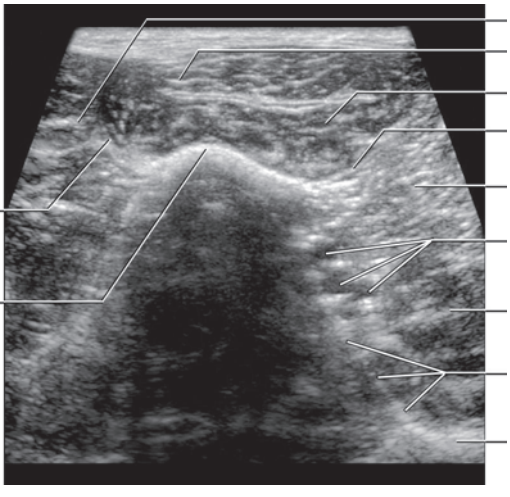
LEG MUSCLES

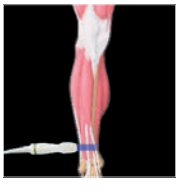
LATERAL COMPARTMENT

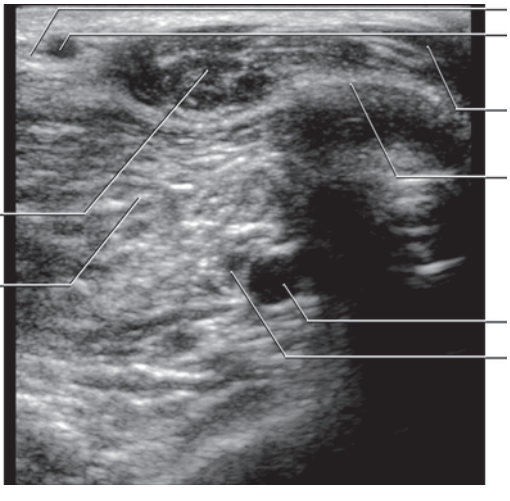




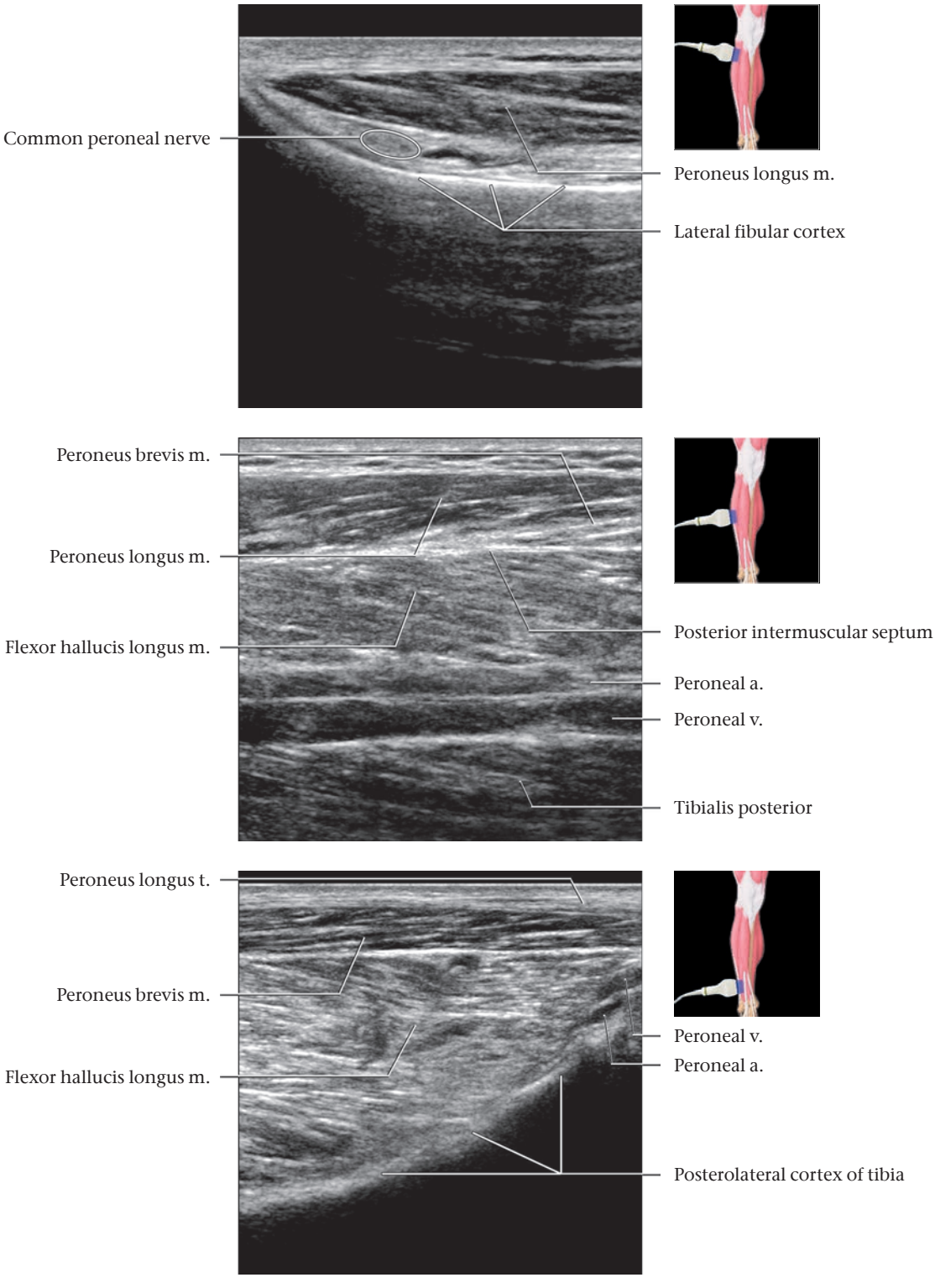








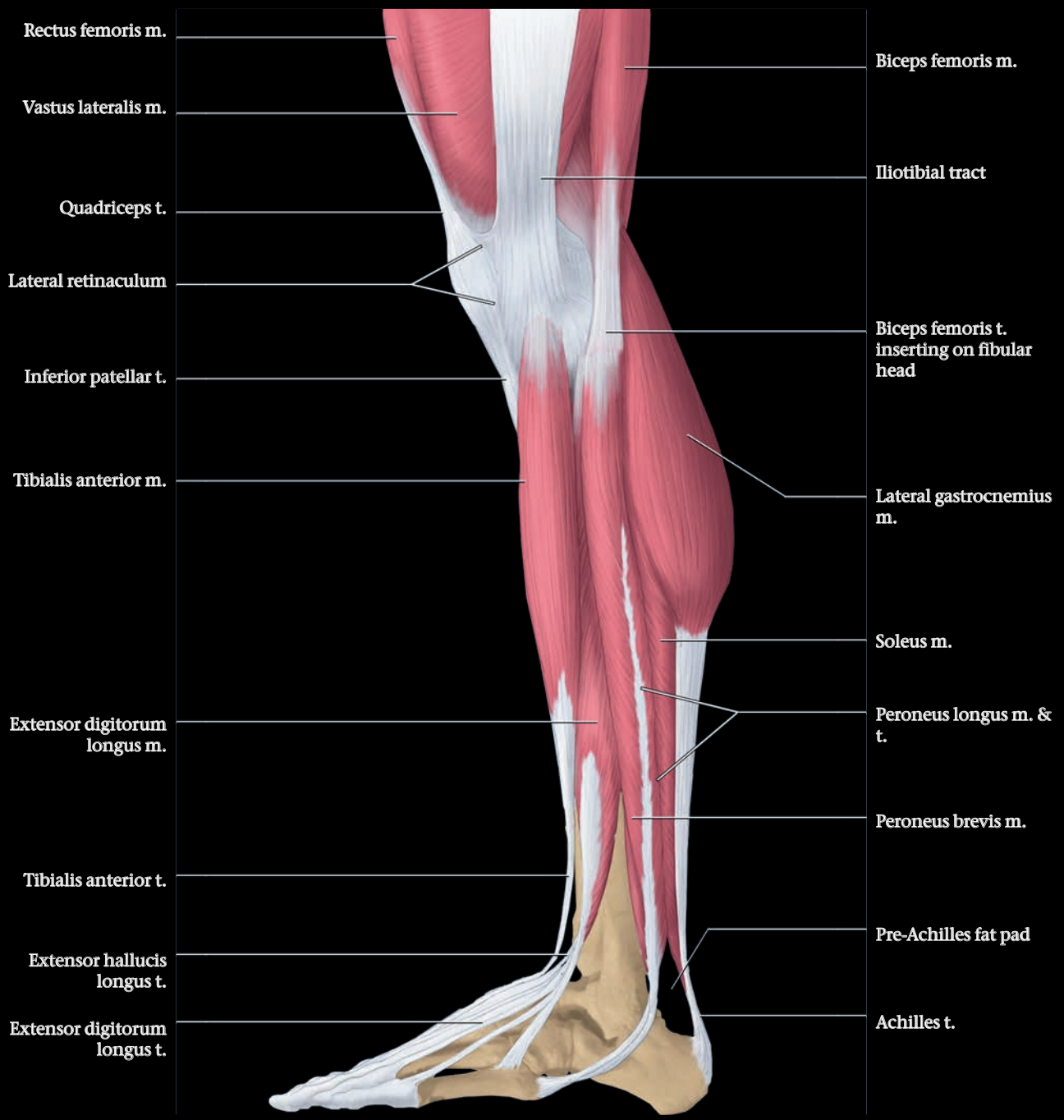
(Top) *Transverse scan shows the lateral compartment at a high level. At this level, only the peroneus longus muscle has originated and is the only muscle occupying this compartment. The superficial peroneal nerve lies on posterior surface of peroneus longus muscle. The deep peroneal nerve has already entered the anterior compartment after curving around the fibular neck (above this scan level).* ***(Middle)*** *Transverse scan at the midleg level shows that the peroneus brevis muscle has now originated and resides anterior and deep to the peroneus longus muscle. More inferiorly, the peroneus longus muscle will become smaller and turn into a tendon while the peroneus brevis will still have muscle fibers down to the level of the ankle joint.* ***(Bottom)*** *Transverse scan shows the level of the lateral malleolus. The peroneal tendons will run posterior to the lateral malleolus and curve around its tip to run toward the lateral foot.*



(Top) *Coronal scan shows the lateral compartment at the level of the fibular neck. The common peroneal nerve runs together with the biceps femoris tendon, then curves anteriorly around the neck of fibula to enter the lateral and then the anterior compartments.* ***(Middle)*** *Coronal scan of the lateral compartment at the midleg level shows the transition between the peroneus longus and peroneus brevis muscles. These are separated from the posterior compartment by the posterior intermuscular septum.* ***(Bottom)*** *Coronal scan further inferiorly shows that the peroneus longus muscle is now only a tendon, compared to the muscular peroneus brevis. Similarly, in the posterior compartment the flexor hallucis longus muscle is the only muscle at this level, as the others have also become tendons.*

LEG MUSCLES

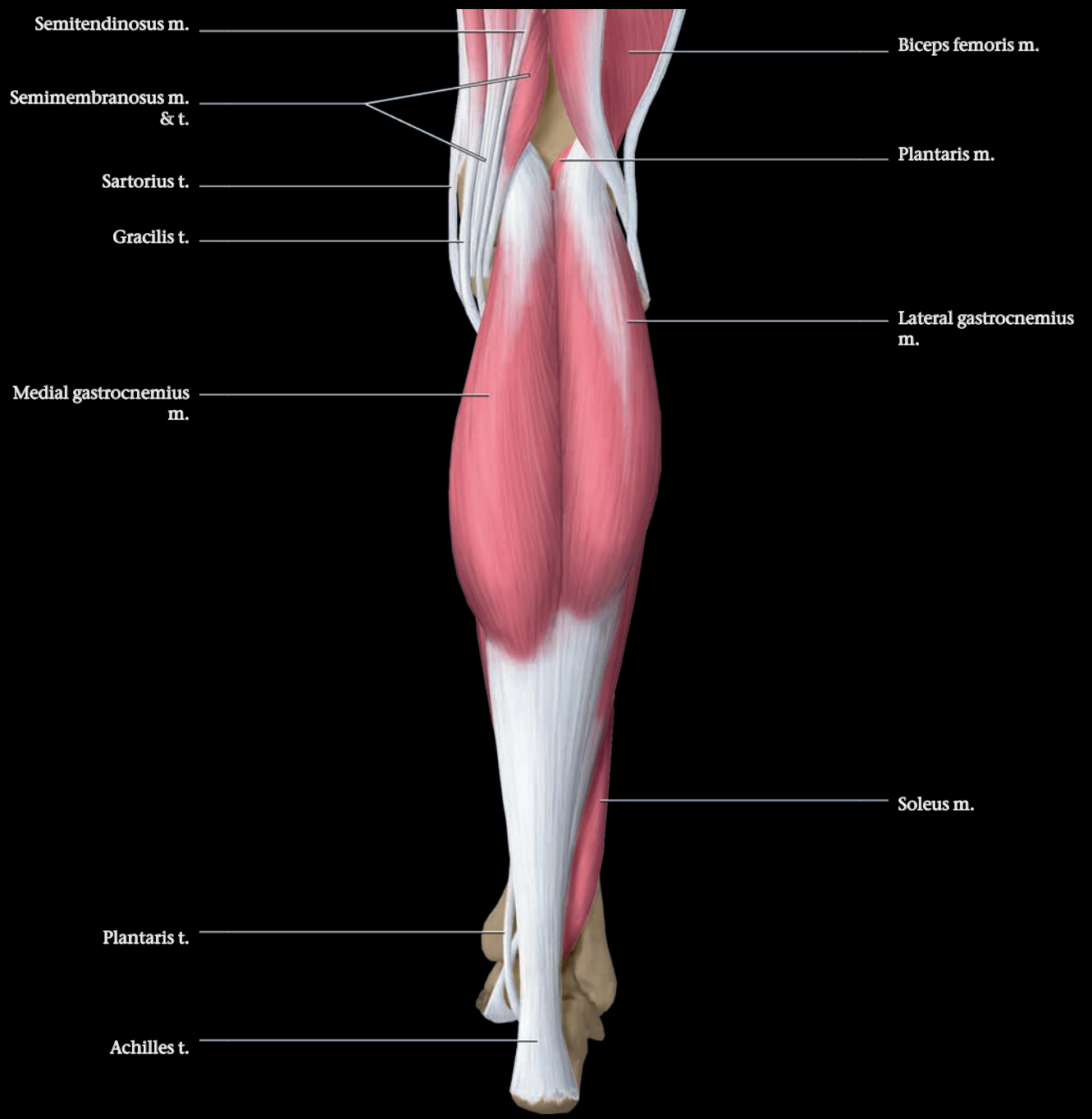
LATERAL LEG



Graphic of the lateral leg shows the anterior compartment (extensors), lateral compartment (peroneals), and superficial muscles of the posterior compartment. Of the ankle tendons, tendinosis most commonly affects the Achilles tendon, the posterior tibialis tendon and the peroneal tendons. The tibialis anterior tendon is also affected though less commonly. As the peroneus brevis lies closest to the bone, it is more prone to trauma particularly in the retromalleolar region. Typically, this tear consists of a longitudinal split where the overlying peroneus longus tendon pushes into the peroneus brevis tendon splitting it into 2 sections. One may then see 3 rather than 2 tendons behind the lateral malleolus. Another reason to see 3 tendons behind the lateral malleolus is when there is a quartus tendon present.

LEG MUSCLES

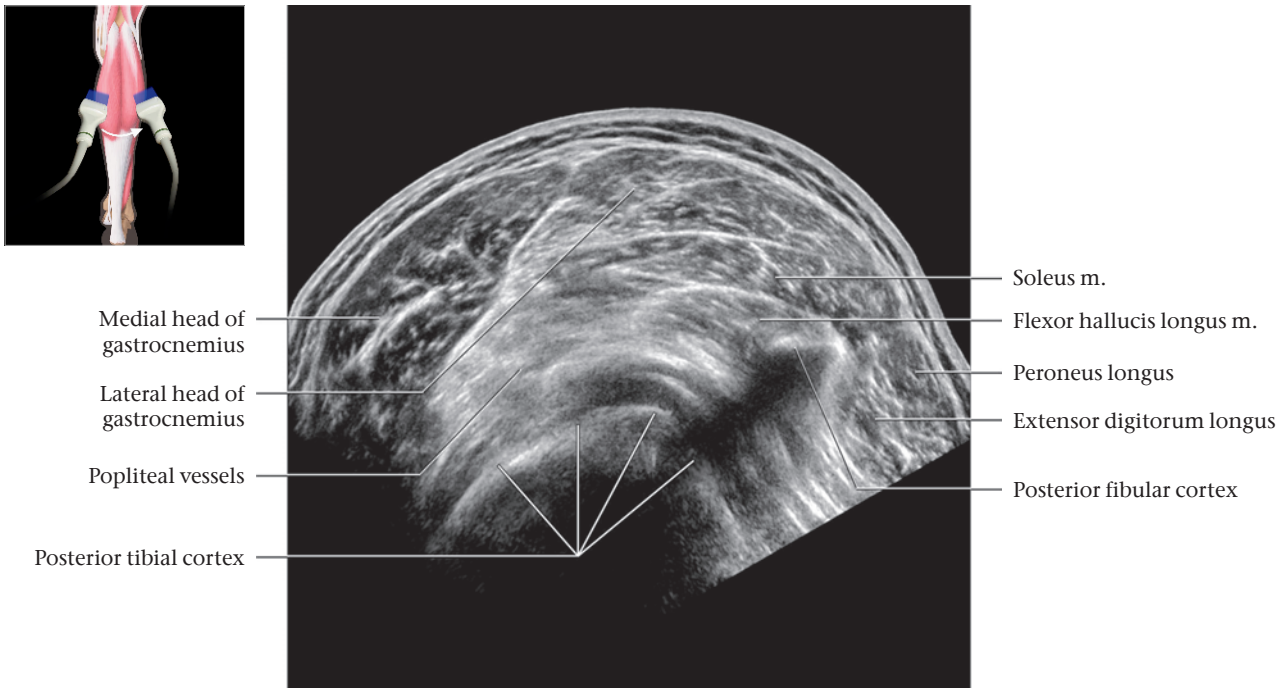
POSTERIOR LEG

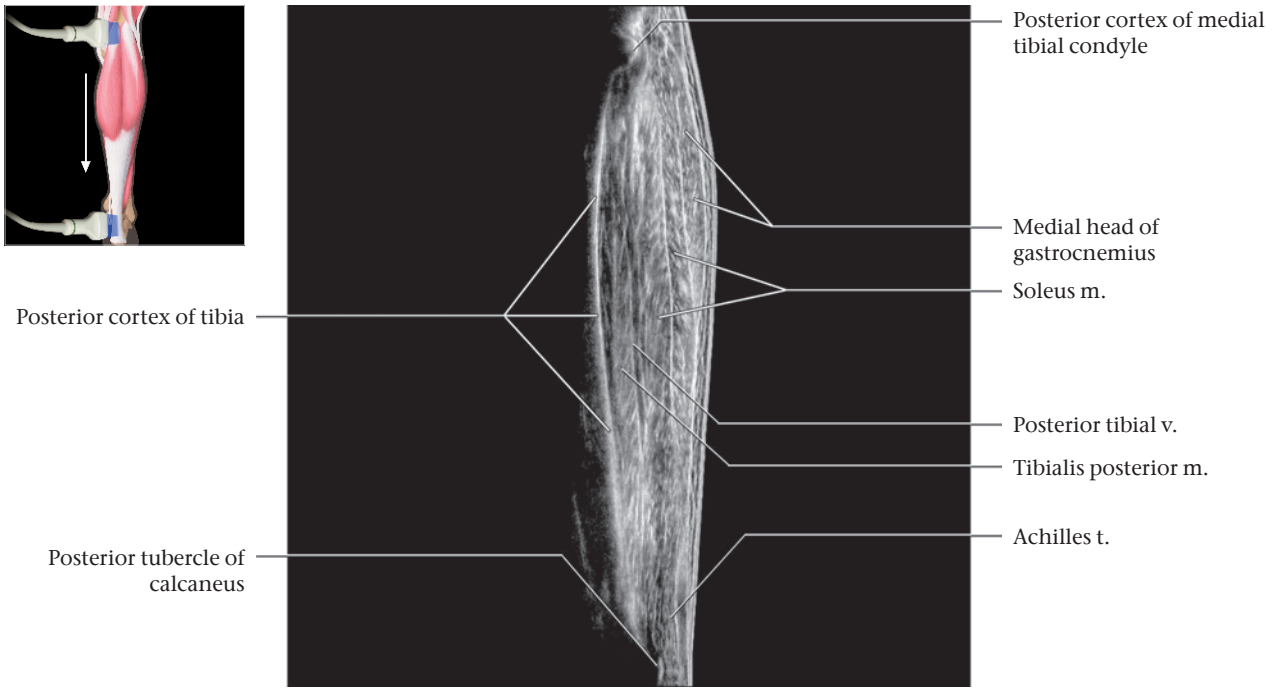


Posterior view shows superficial muscles and tendons of the leg. The gastrocnemius muscles are bulky in the proximal half of the leg and taper to an aponeurosis, which blends with the soleus more distally to become the Achilles tendon. The plantaris muscle is superficial only at its origin from the lateral femoral metaphysis, just medial to the origin of the lateral head of gastrocnemius. The muscle extends only a few centimeters before becoming tendinous, extending distally between the soleus and medial gastrocnemius. Eventually, the plantaris tendon merges with the medial side of the Achilles or inserts on the calcaneus, medial to the Achilles insertion.

LEG MUSCLES

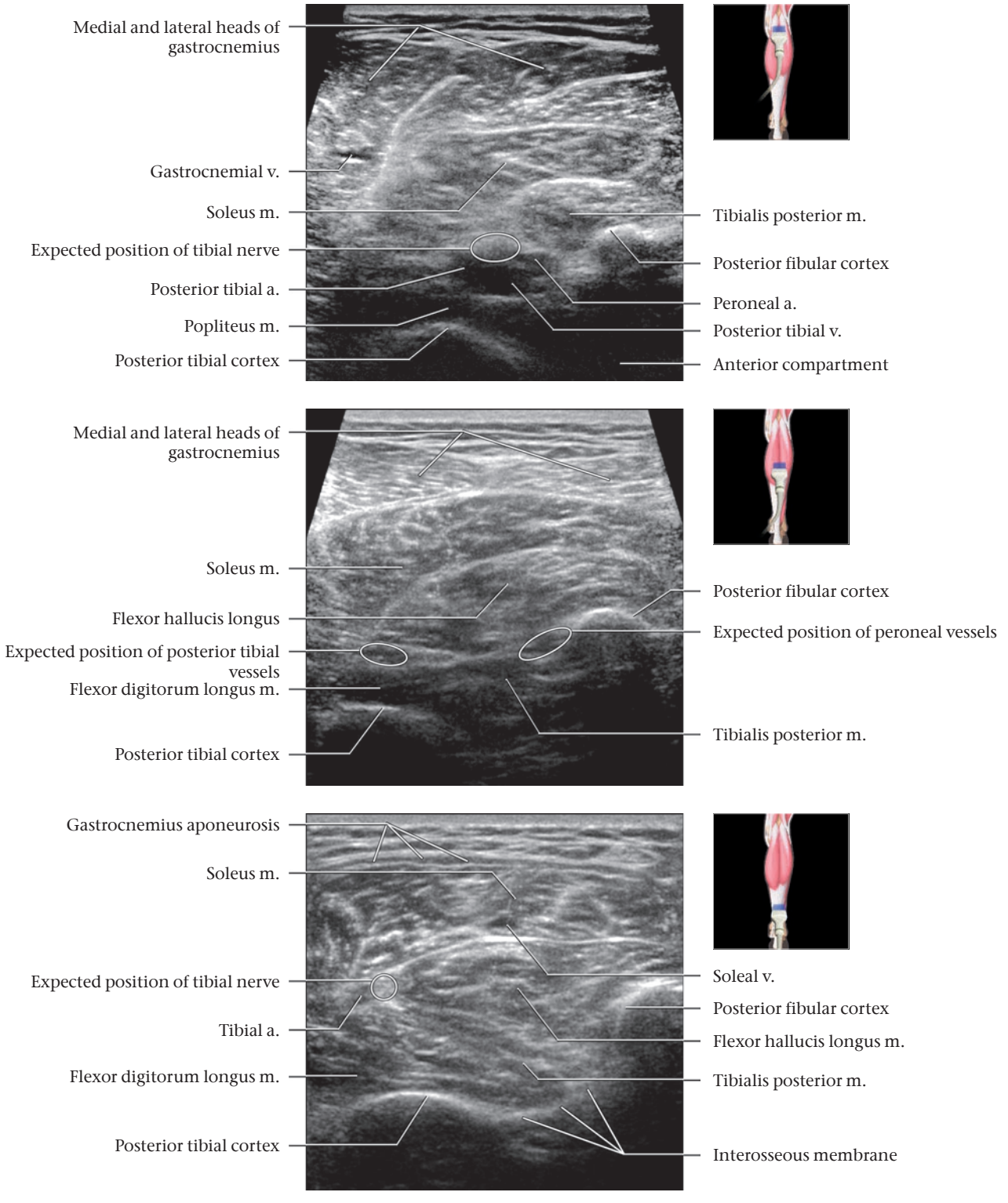
PANORAMIC POSTERIOR LEG





(Top) *Transverse panoramic scan shows the posterior compartment at the level of the midleg. The medial head of the gastrocnemius muscle is larger than the lateral throughout its course. From this midcalf level downwards, the soleus will assume relatively more bulk as the gastrocnemius turns tendinous.* ***(Bottom)*** *Sagittal panoramic scan shows the posterior compartment. The gastrocnemius is muscular down to approximately the level of the midcalf. Below this level, it forms the Achilles tendon, receiving contributions from the soleus muscle. For the deep layer, the tibialis posterior muscle lies on the surface of the tibial shaft and interosseous membrane.*

TRANSVERSE POSTERIOR LEG



(Top) *Transverse scan is seen through the posterior compartment at the upper-calf level. For this compartment, the superficial layer consists of the gastrocnemius, plantaris, and soleus muscles. The deep layer consists of the popliteus, tibialis posterior, flexor digitorum longus, and flexor hallucis longus muscles.* ***(Middle)*** *Transverse scan shows the midcalf level. The tibial vessels have bifurcated into their peroneal and posterior tibial branches, which delineates a separation between the tibialis posterior and flexor digitorum longus from the rest of the calf muscles. Given the thickness of the gastrocnemius and soleus muscle, these deep muscles may be better seen using the anterior compartment as a window.* ***(Bottom)*** *Further inferiorly, the gastrocnemius has become a thin aponeurosis and together with the tendon from the soleus muscle will form the Achilles tendon.*

LEG VESSELS

TERMINOLOGY

Abbreviations

- Artery (a.)
- Ligament (l.)
- Muscle (m.)
- Nerve (n.)
- Vein (v.)
- Tendon (t.)

GROSS ANATOMY

Vessels of Leg

- **Popliteal artery**
  - Begins as continuation of superficial femoral artery after it has passed through adductor hiatus (inferior end of adductor canal)
  - Runs through fat of popliteal fossa
  - Relationships
    - Deep to artery: Femoral shaft, knee joint capsule, popliteus fascia
    - Superficial to artery: Popliteal vein, semimembranosus muscle, and gastrocnemius muscle
  - Artery lies just deep to vein in 40%, deep and medial to vein in 43%, deep and lateral to vein in 9%, and just medial or lateral to vein in 8%
  - Ends at distal border of popliteus muscle dividing into 2 branches: Anterior tibial artery and tibioperoneal trunk
- **Anterior tibial artery**
  - Smaller of the 2 terminal branches of popliteal artery
  - Origin in back of leg, at distal border of popliteus muscle
  - Passes through upper part of interosseous membrane
  - Straight course down front of leg to become dorsalis pedis artery
  - Runs on anterior surface of interosseous membrane, deep to extensor muscles
  - Muscular branches along length
  - Malleolar branches ramify over malleoli; lateral branch anastomoses with perforating branch of peroneal artery
- **Posterior tibial artery**
  - Larger of 2 terminal branches of popliteal artery
  - Main blood supply to foot
  - Passes downwards and slightly medially along with tibial nerve to end in space between medial malleolus and calcaneus
  - Within calf, artery runs just deep to transverse intermuscular septum
  - Divides into lateral and medial plantar arteries in tarsal tunnel behind medial malleolus
  - Branches
    - Circumflex fibular (may arise from anterior tibial), runs laterally around neck of fibula
    - Nutrient artery to tibia
    - Muscular branches
- **Peroneal artery**
  - Largest branch of posterior tibial artery
  - Runs obliquely downward and laterally beneath soleus to fibula
  - Descends deep to flexor hallucis longus
- **Popliteal vein**
  - Paired venae comitantes of anterior and posterior tibial arteries join to form popliteal vein
  - Also receives small saphenous vein in popliteal fossa
  - Usually begins at inferior border of popliteus muscle
  - Crosses from medial to lateral side of popliteal artery as it runs in the popliteal fossa, aside from always being superficial to popliteal artery
  - Ends at adductor hiatus by becoming superficial femoral vein
- **Great saphenous vein**
  - Begins at medial border of foot
  - Ascends in front of medial malleolus
  - Passes obliquely upward and backward across medial surface of distal 1/3 of tibia
  - Passes vertically upward along medial border of tibia to posterior part of medial side of knee
- **Small saphenous vein**
  - Extends behind lateral malleolus, ascends lateral to Achilles tendon
  - At midline of calf in lower popliteal region, pierces popliteal fascia, and terminates in popliteal vein

ANATOMY IMAGING ISSUES

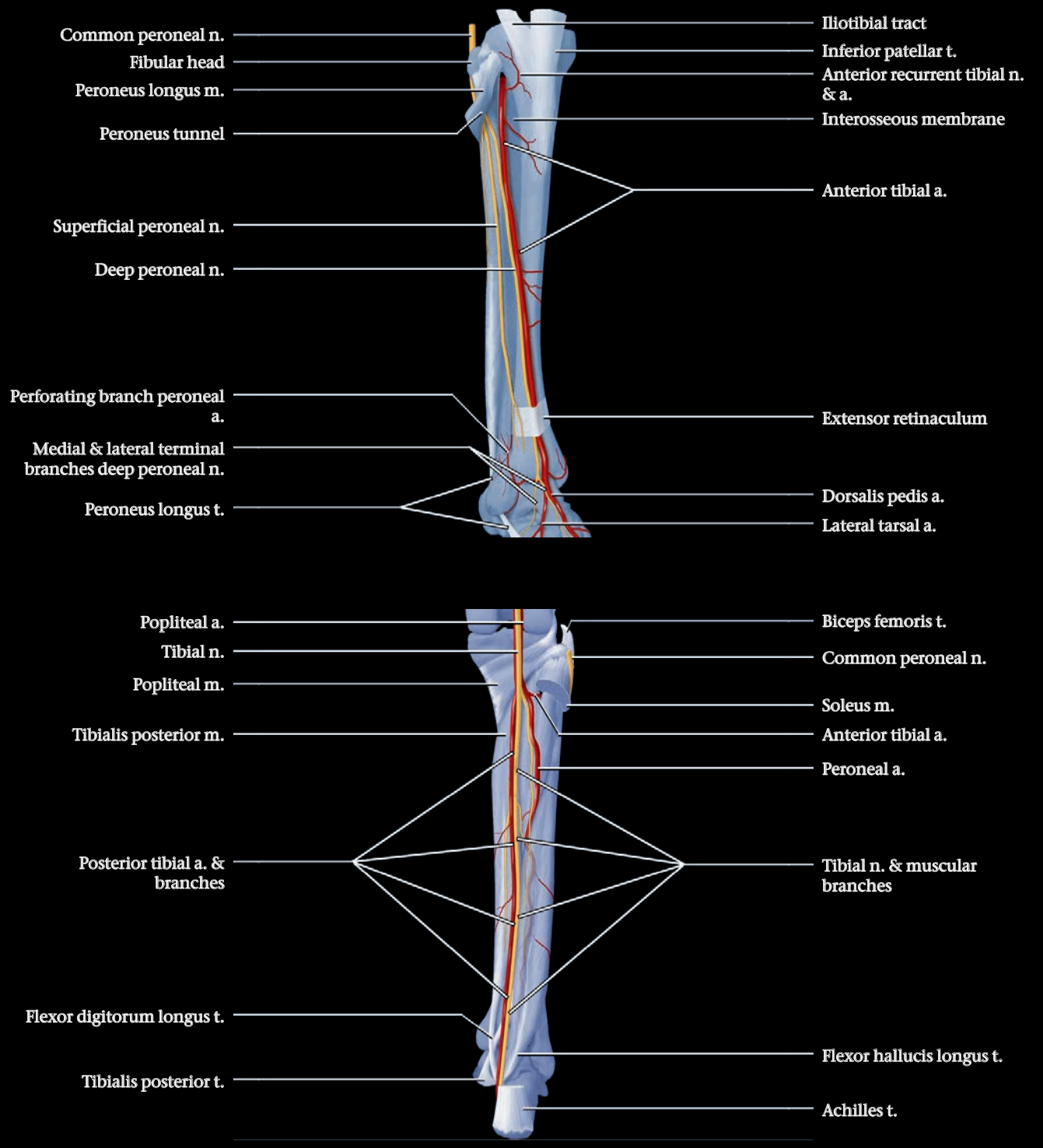
Imaging Recommendations

- Ultrasound
  - Examination of lower limb vessels requires use of morphological and functional techniques
    - Morphology: Documentation of areas of stenosis or occlusion, sites of venous valves, aberrant branches, aneurysm formation, etc.
    - Functional: Combination of color and spectral Doppler examination
  - Veins require use of dynamic maneuvers
    - Valsalva: To increase abdominal pressure and accentuate reverse flow and incompetent venous valves
    - Augmentation: To increase venous return (to demonstrate venous flow and patency) by manually squeezing calf or by gently moving toes
    - Compression: To demonstrate absence of thrombus by using transducer pressure to cause complete luminal occlusion
  - Arteries require use of spectral Doppler scanning to show their phasicity; normal scan is triphasic
    - Sharp forward flow upstroke (systolic phase)
    - Small reverse flow (early diastolic phase)
    - Final smaller forward flow (late diastolic phase)

Imaging Pitfalls

- Augmentation is frequently required to demonstrate flow in deep calf veins (which normally show no color Doppler flow)

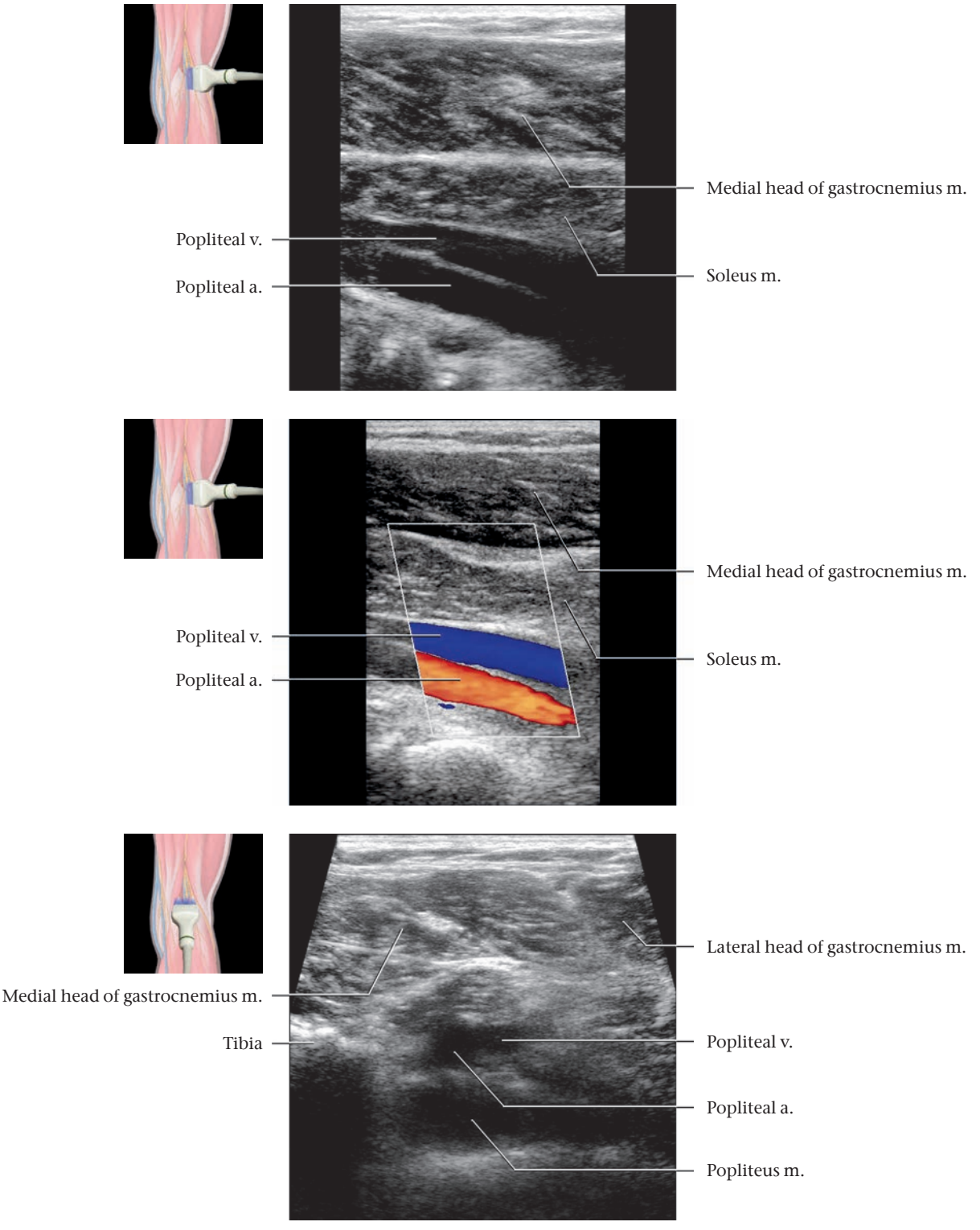
GRAPHICS, ANTERIOR AND POSTERIOR LEG VESSELS



*(**Top**) Graphic of anterior leg shows the anterior tibial artery perforating the interosseous septum proximally and descending along this membrane down the front of leg to terminate as the dorsalis pedis. Distally, one sees a perforating branch of the peroneal artery, which in a variant situation may provide the major blood supply to the dorsum of the foot. (**Bottom**) The popliteal artery ends at the distal border of popliteus in 2 branches: (1) Anterior tibial artery passes through a slit in the tibialis posterior muscle and the interosseous membrane to the anterior compartment, and (2) the posterior tibial artery passes downwards and slightly medially adjacent to the tibial nerve to end in the space between the medial malleolus and calcaneus. The largest branch of the posterior tibial artery is the peroneal artery, which runs obliquely downward and laterally beneath the soleus to the fibula.*

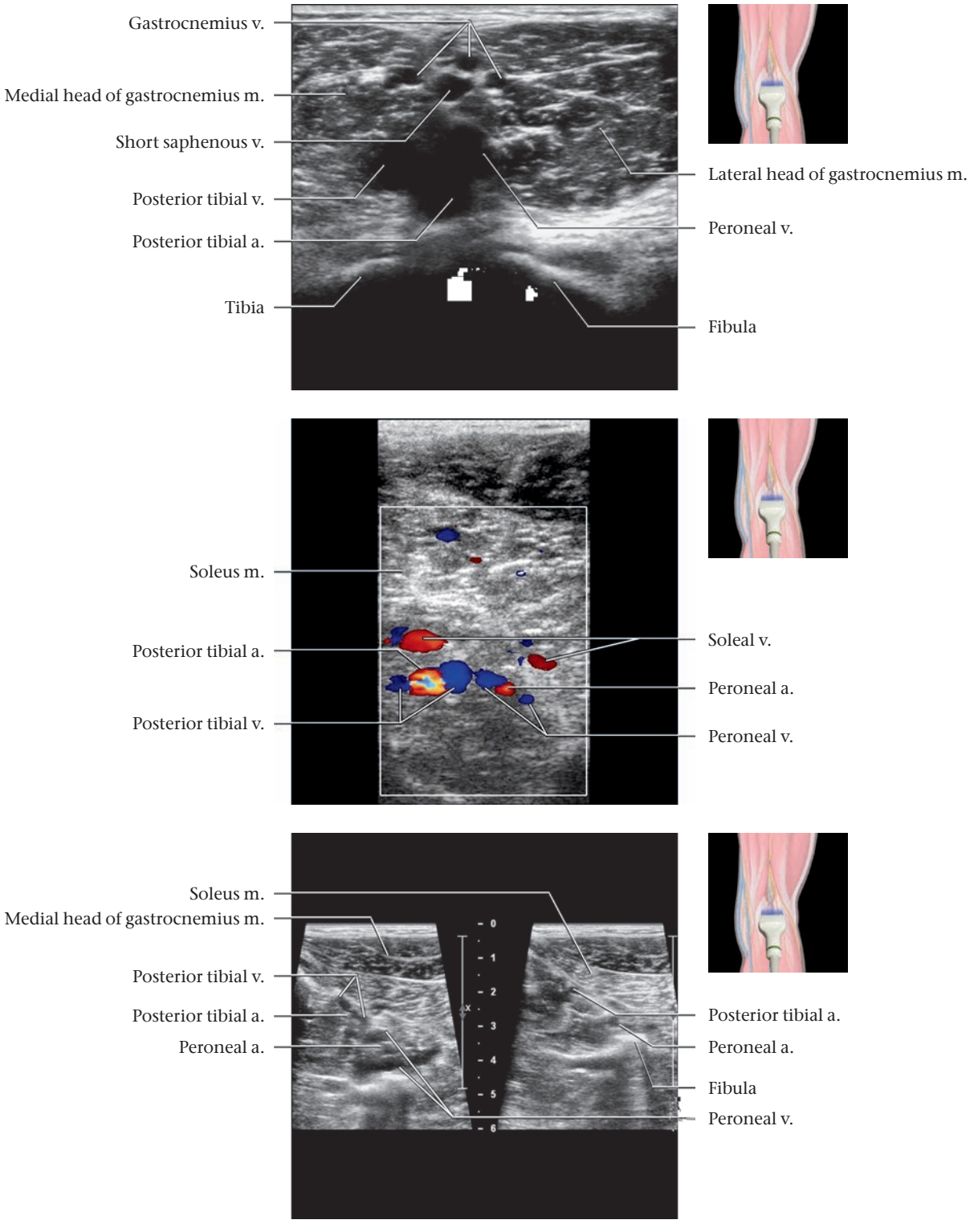
LEG VESSELS

POPLITEAL VESSELS



(Top) *Sagittal scan shows the lower part of the popliteal vessels. The popliteal vessels are continuations of the superficial femoral vessels after they have exited the adductor canal through the adductor hiatus. The popliteal vein lies superficial to the popliteal artery, a reverse of the relationship between the superficial femoral vein and artery. The popliteal vessels pass inferolaterally through the fat of the popliteal fossa.* ***(Middle)*** *Sagittal color Doppler scan of the popliteal vessels shows complete color filling of the lumina (excluding luminal thrombus) and normal flow direction: Toward the trunk (blue) for the vein and away from the trunk (red) for the artery.* ***(Bottom)*** *Transverse scan shows the lower part of the popliteal vessels. The popliteal vein runs superficial to the popliteal artery and usually bifurcates at the inferior margin of the popliteus muscle.*

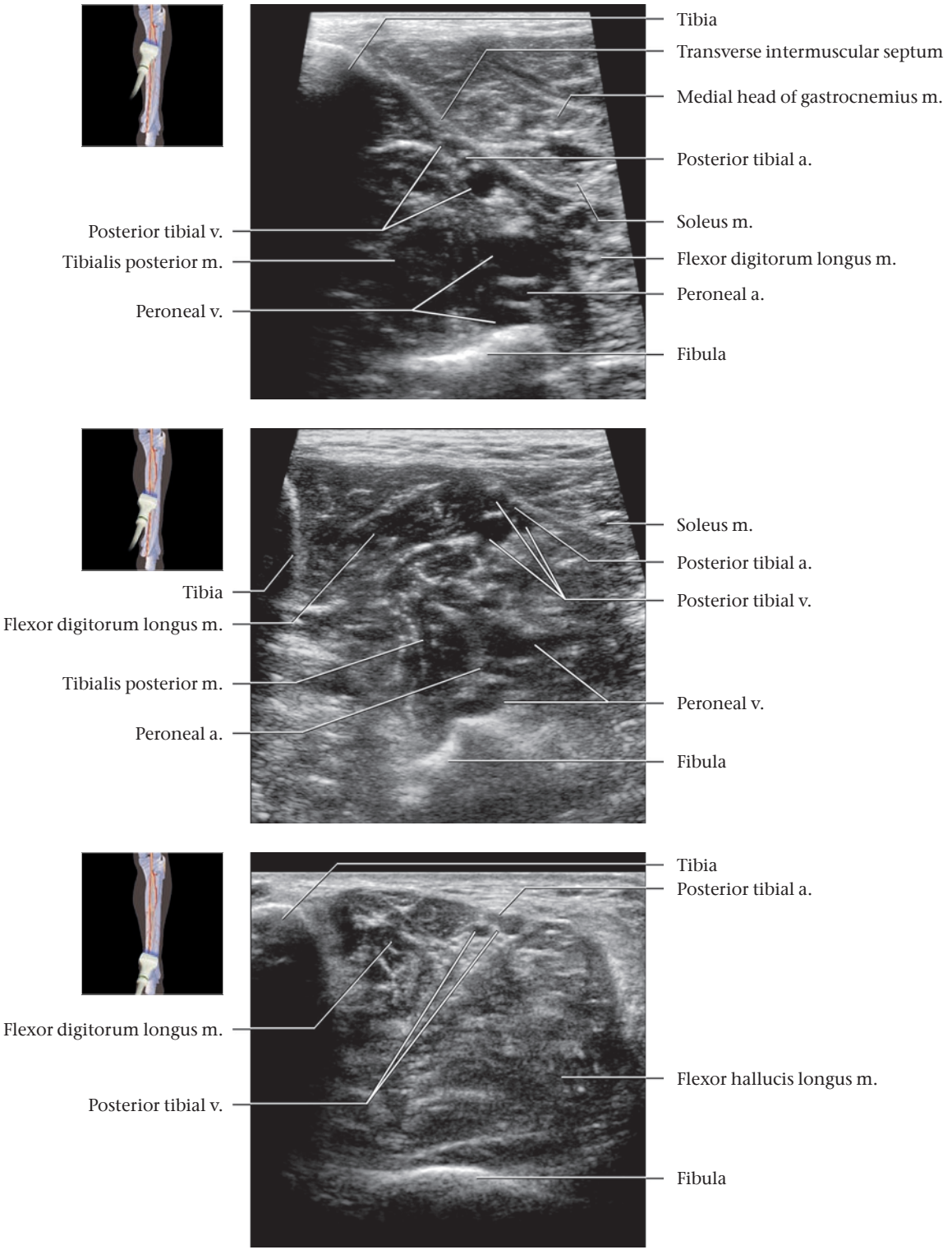
POPLITEAL VESSEL BIFURCATION



(Top) *Transverse scan below the bifurcation of the popliteal artery is shown. The popliteal artery bifurcates into the anterior and posterior tibial arteries. The posterior tibial artery is the larger of the 2 terminal branches of the popliteal artery and passes inferiorly for a short distance before giving out its largest branch, the peroneal artery.* ***(Middle)*** *Transverse color Doppler scan shows the posterior compartment vessels of the proximal calf. Color flow highlights the paired venae comitantes nature of the posterior tibial and peroneal veins, lying on both sides of the corresponding artery.* ***(Bottom)*** *Transverse scan at the mid-proximal calf scanning from the medial side is shown. The lumina of the peroneal and tibial veins can be compressed by firm transducer pressure (right 1/2 of image), indicating the lack of thrombus.*

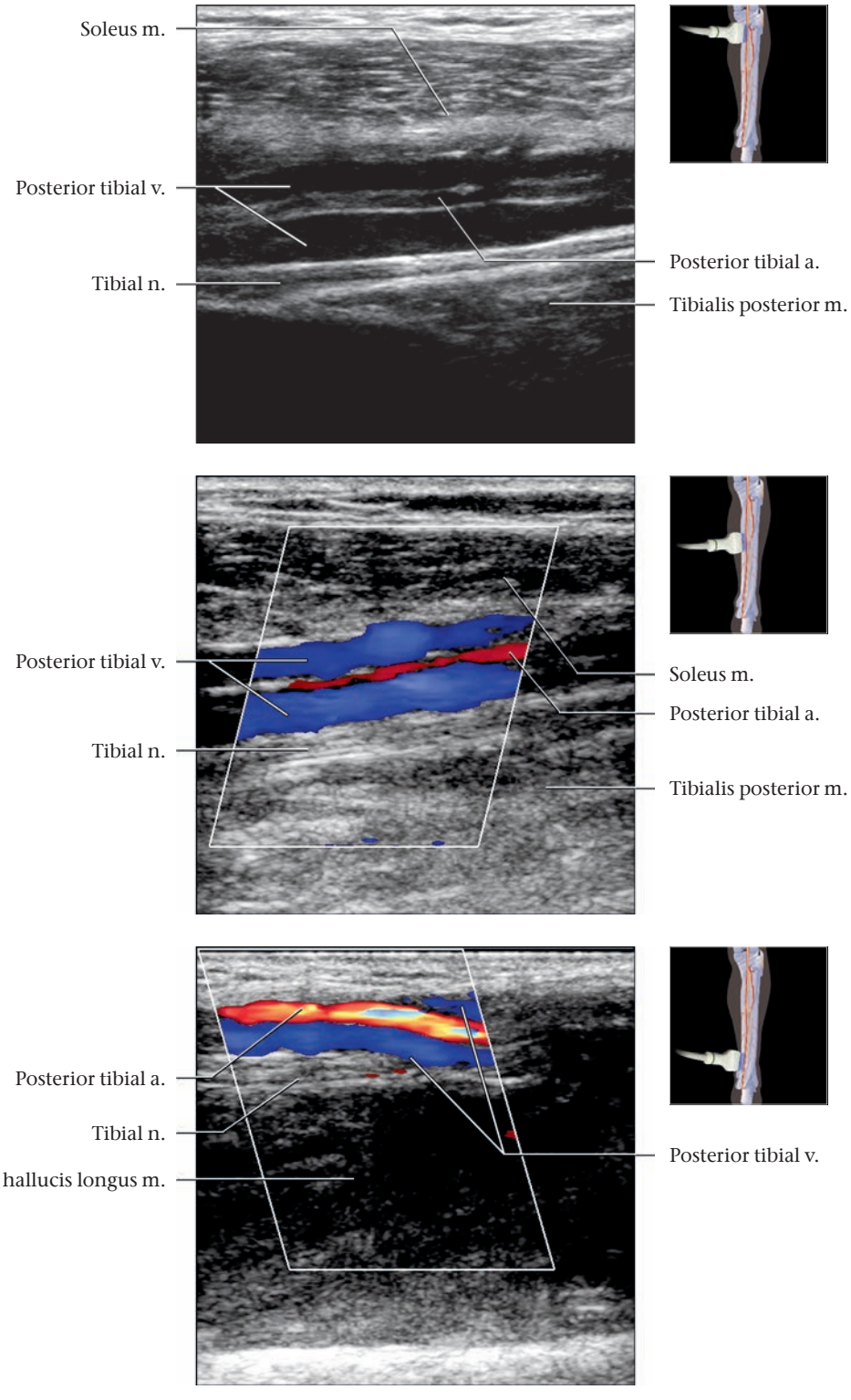
LEG VESSELS

TRANSVERSE POSTERIOR TIBIAL VESSELS



(Top) *Three transverse scans show the posterior tibial vessels using a medial scanning approach. Superiorly, the posterior tibial vessels give off their main branches, the common peroneal vessels. The posterior tibial artery lies just deep to the transverse intermuscular septum while the peroneal arteries are deep to the flexor digitorum muscle.* ***(Middle)*** *At the midcalf level, the posterior tibial vessels no longer line up side by side (3 in a line). Anatomical variations occur, as seen here with 3 posterior tibial veins accompanying 1 artery. The peroneal vessels continue their deeper course, running on the surface of the tibialis posterior, which separates them from the anterior leg compartment.* ***(Bottom)*** *Further inferiorly, the posterior tibial vessels emerge superficially as they prepare to enter the tarsal tunnel behind the medial malleolus.*

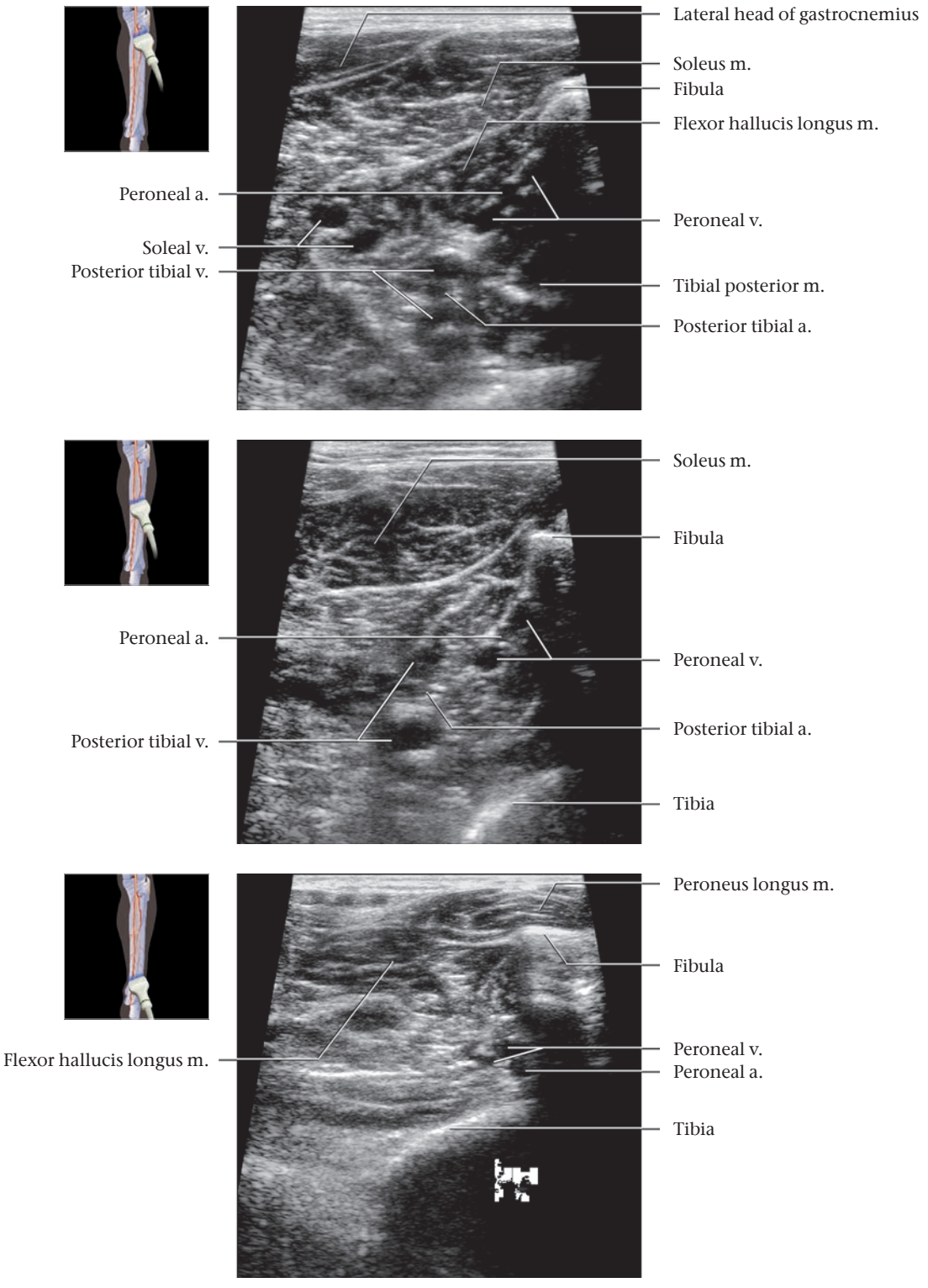
LONGITUDINAL POSTERIOR TIBIAL VESSELS



(Top) *Oblique coronal scan shows the posterior tibial vessels using a medial approach. The posterior tibial artery is accompanied by paired venae comitantes (posterior tibial veins) and the tibial nerve. They run deep to the transverse intermuscular septum of the leg.* ***(Middle)*** *Color Doppler scan shows the posterior tibial vessels. Notice the marked difference in caliber between the artery and the veins, all of which show normal, complete color filling and normal direction of flow.* ***(Bottom)*** *Further inferiorly, oblique coronal scan of the lower calf shows the distal part of the posterior tibial vessels running superficial to the flexor hallucis muscle and getting ready to curve under the medial malleolus. The posterior tibial vessels and tibial nerve run in the tarsal tunnel together with the tendon flexors of the foot.*

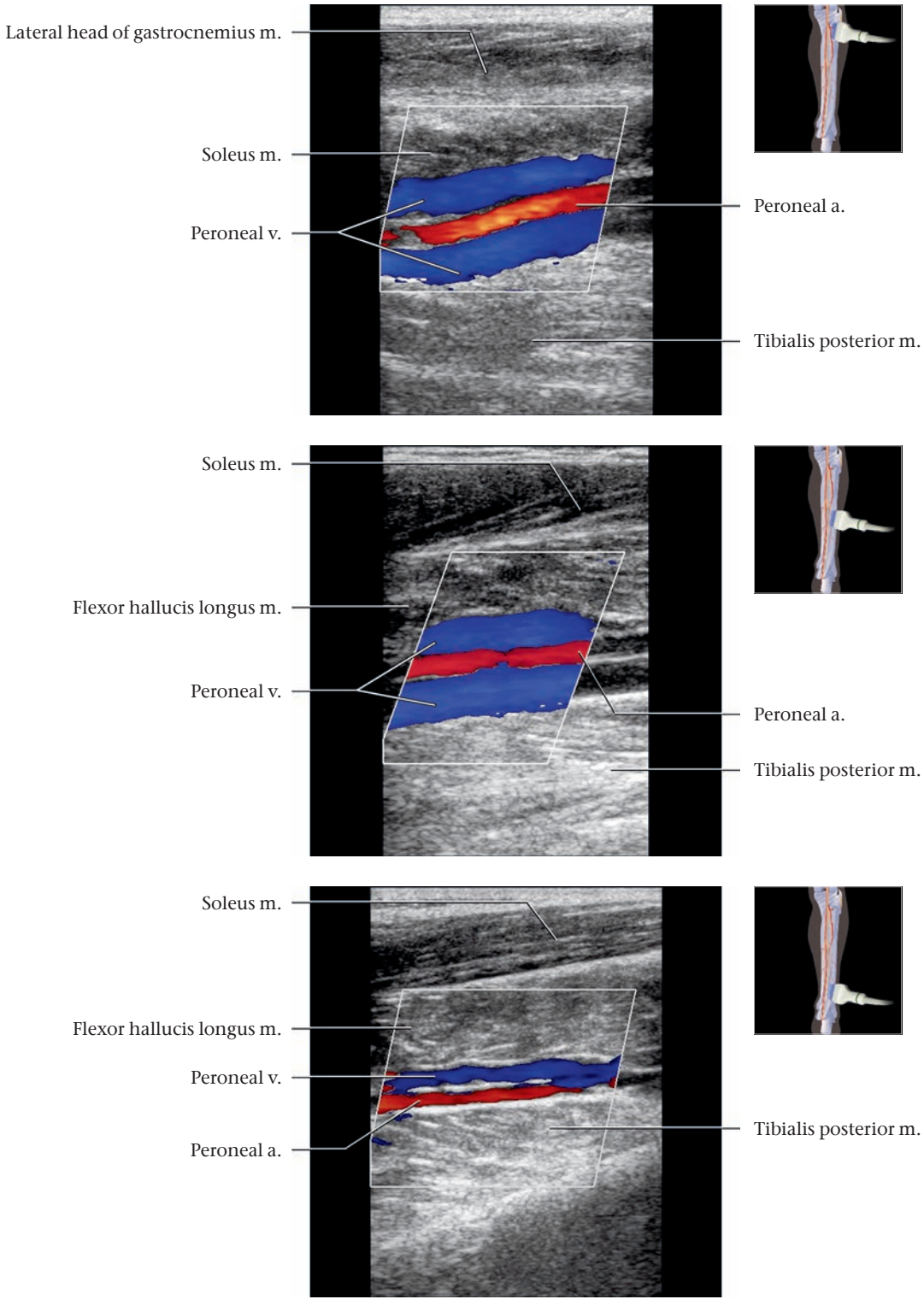
LEG VESSELS

TRANSVERSE PERONEAL VESSELS



(Top) *Three transverse scans of the calf using a lateral scanning approach is shown. The peroneal artery is a branch of the posterior tibial artery. It runs obliquely toward the fibula and then run along the medial surface of the fibula distally, sandwiched between the flexor hallucis longus muscle and tibialis posterior muscle.* ***(Middle)*** *More distally, the relationship between the peroneal vessels and the fibula and flexor muscles remains the same. Nutrient vessels branch out to supply the fibula and the adjacent muscles.* ***(Bottom)*** *Most distally, the peroneal artery runs behind the tibiofibular syndesmosis before dividing into lateral calcaneal branches which run over the lateral and posterior surfaces of the calcaneum.*

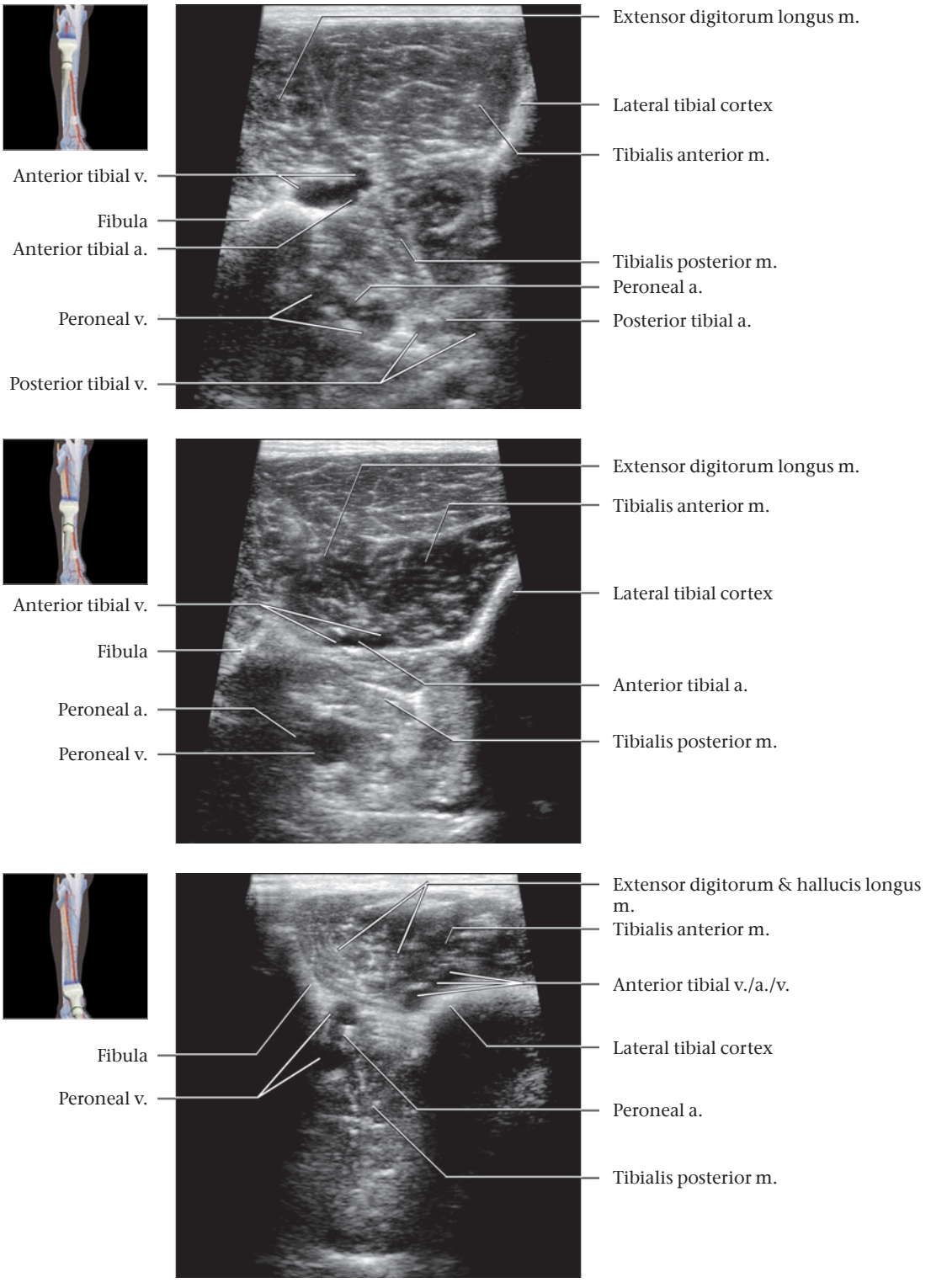
LONGITUDINAL PERONEAL VESSELS



(Top) *Oblique coronal scan shows the peroneal vessels using a lateral approach. The peroneal artery, like the posterior tibial, is also accompanied by venae comitantes (peroneal veins). The difference is that there is no peroneal nerve to accompany the vessels. The peroneal nerve runs in the lateral leg compartment after curving around the neck of the fibula.* ***(Middle)*** *More inferiorly, oblique coronal scan shows the peroneus vessels lie deep to the flexor hallucis longus and soleus muscles, while running superficial to the tibialis posterior muscle.* ***(Bottom)*** *Further inferiorly, the peroneal vessels are much smaller in caliber after giving out many branches. They pass posterior to the tibiofibular syndesmosis.*

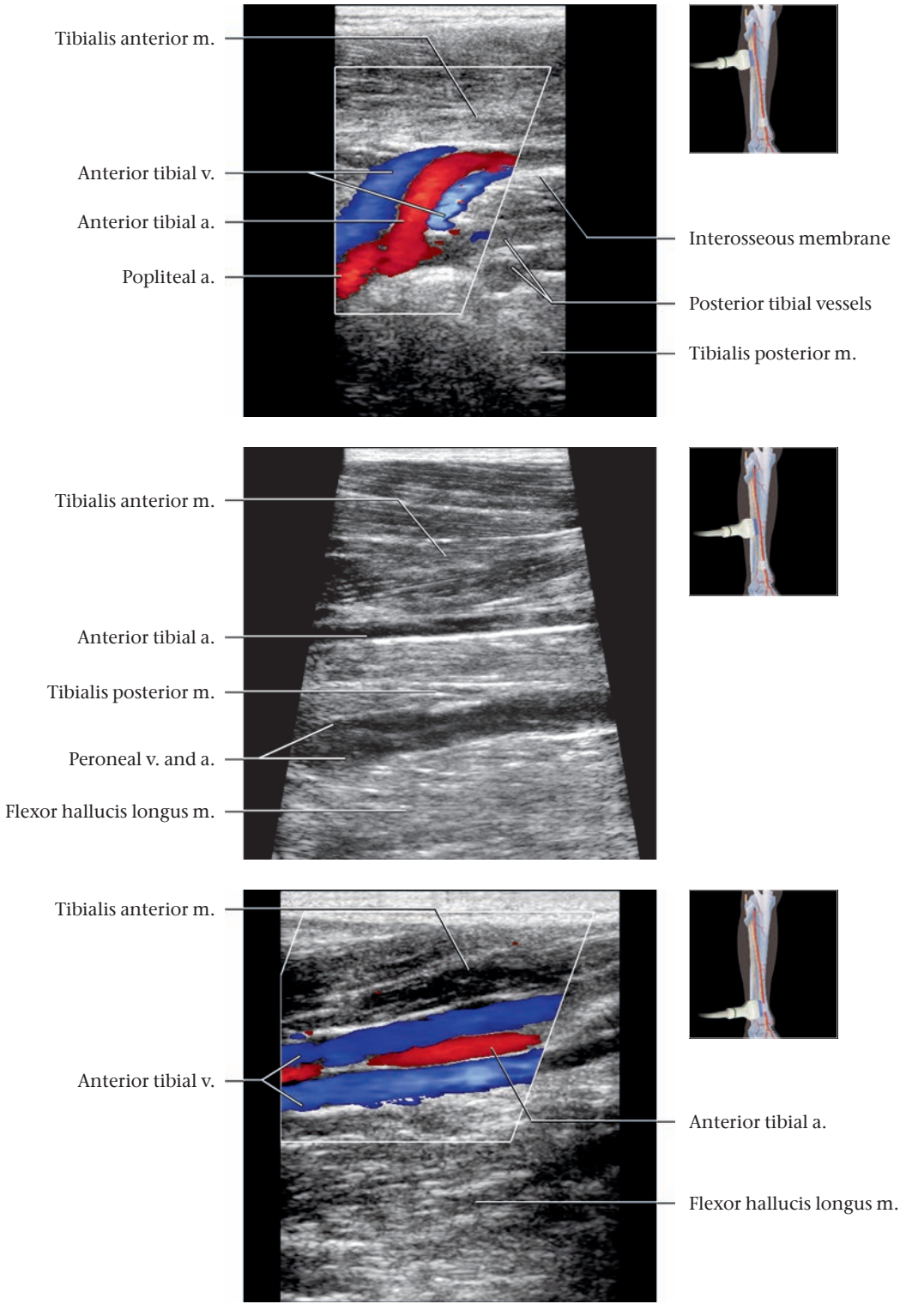
LEG VESSELS

TRANSVERSE ANTERIOR TIBIAL VESSELS



(Top) *Three transverse scans show the anterior tibial vessels using an anterior scanning approach. The anterior tibial vessels are the smaller terminal branches of the popliteal vessels (smaller compared to the posterior tibial vessels at the bifurcation). After its origin, the anterior tibial vessels run anterior through the interosseous membrane and then pass inferiorly on the anterior surface of this membrane.* ***(Middle)*** *At midleg level, the anterior tibial vessels continue to run in a deep position on the surface of the interosseous membrane. Through the window between the tibia and fibula, the peroneal vessels and tibialis posterior muscle are seen.* ***(Bottom)*** *In the most distal part of the leg, the anterior tibial vessels move medially to lie on the surface of the tibia. At this level, the peroneal artery branches run anteriorly to penetrate the interosseous membrane.*

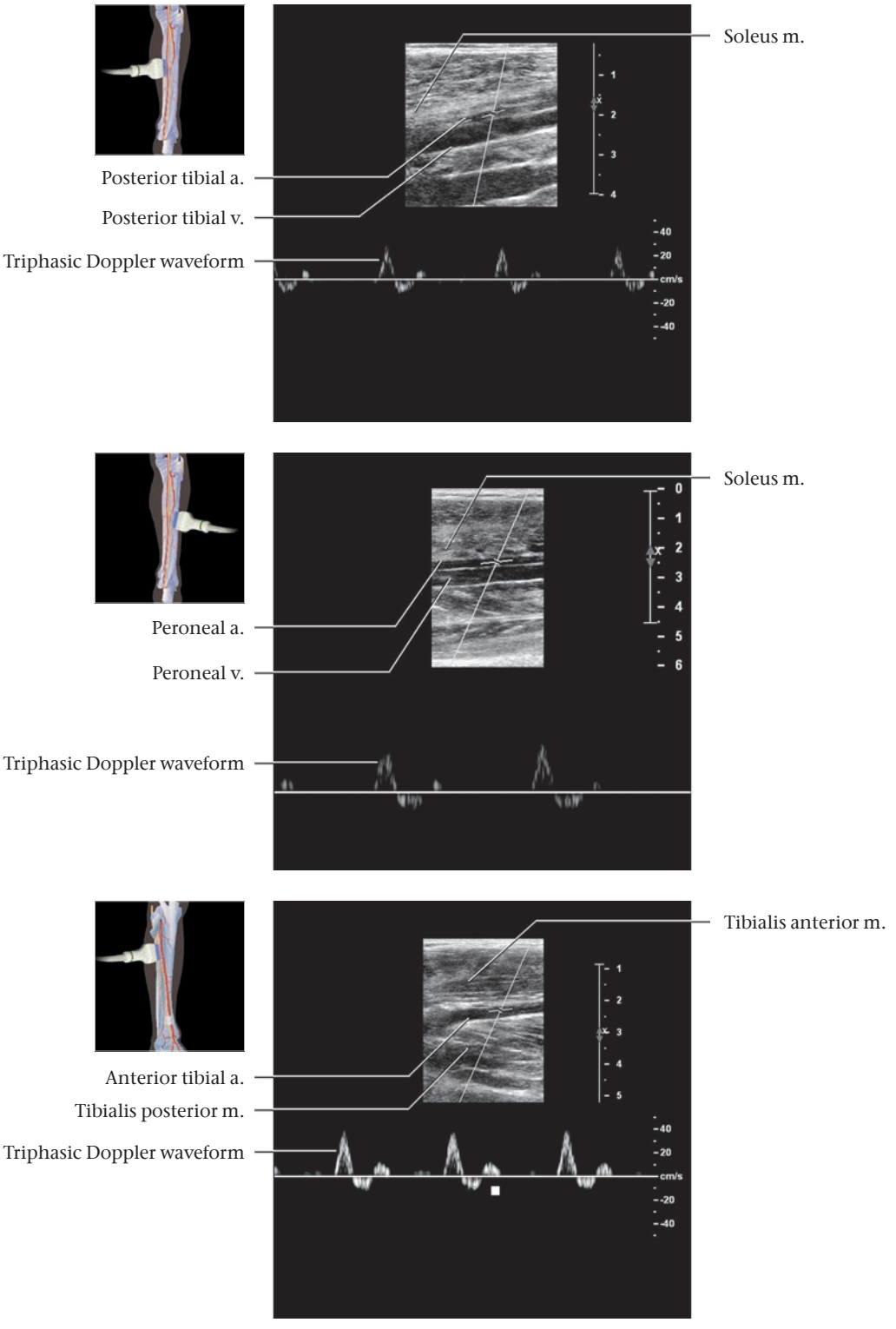
LONGITUDINAL ANTERIOR TIBIAL VESSELS



(Top) *Oblique sagittal color Doppler scan shows the anterior tibial vessels as they bifurcate from the popliteal vessels. The anterior tibial vessels run anteriorly to penetrate the interosseous membrane into the anterior compartment.* ***(Middle)*** *Sagittal scan shows the anterior tibial artery in the midleg level. The anterior tibial artery runs deep within the anterior compartment and on the surface of the interosseous membrane, being covered by the tibialis anterior muscle.* ***(Bottom)*** *Sagittal color Doppler scan shows the lower aspect of the anterior tibial vessels. The vessels begin to run more superficially, and in the foot, the anterior tibial artery continues as the dorsalis pedis artery.*

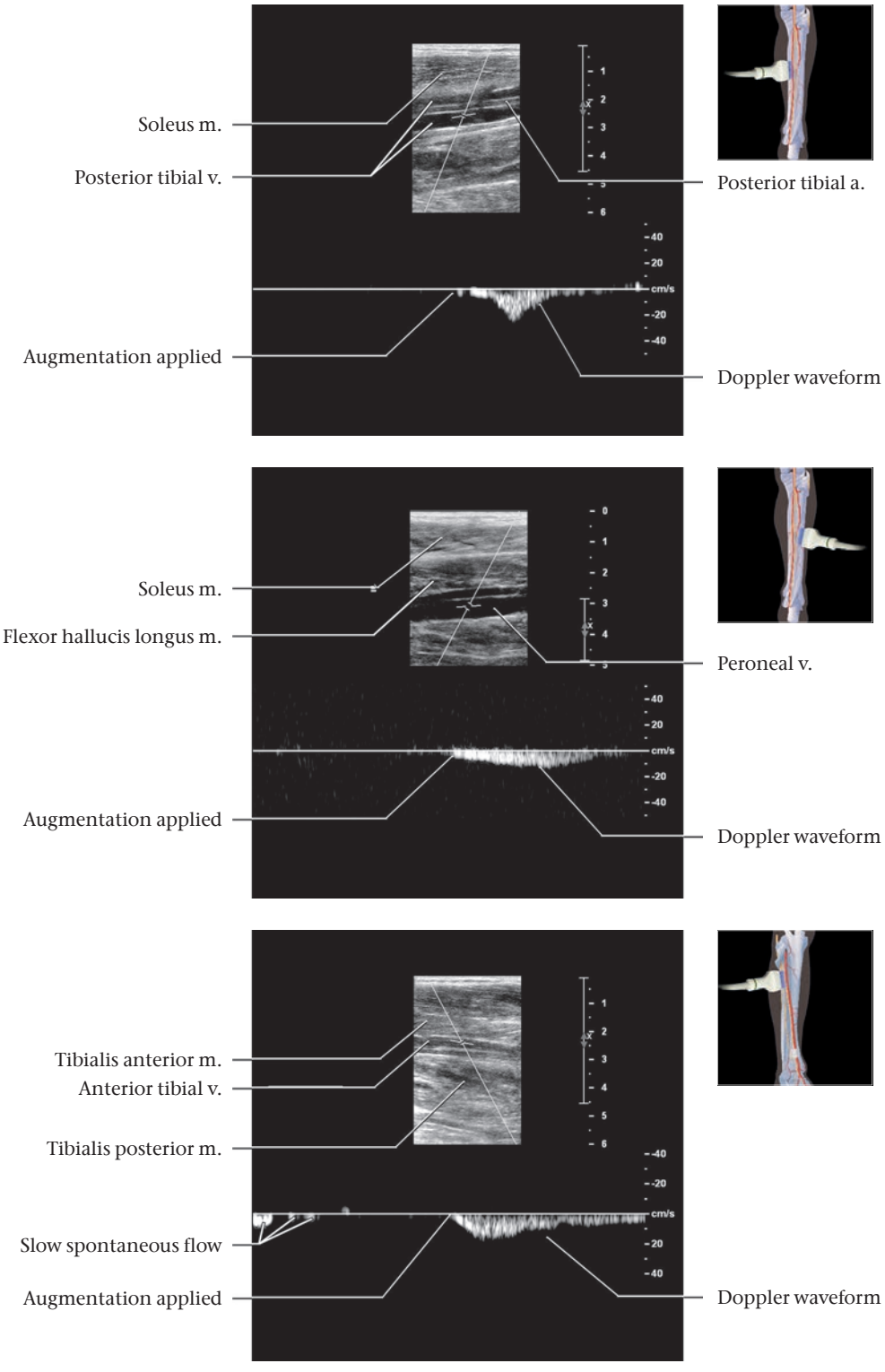
LEG VESSELS

SPECTRAL DOPPLER OF LEG ARTERIES



(Top) *Spectral Doppler scan of the posterior tibial artery demonstrates the typical triphasic pattern seen in normal arteries. Loss of the reverse flow in the diastolic phase is termed a biphasic pattern and is suggestive of stenosis proximal to the point of interrogation. With proximal stenosis, the peak flow velocity is also decreased.* ***(Middle)*** *Similarly, the peroneal artery shows a triphasic waveform on spectral Doppler.* ***(Bottom)*** *Oblique coronal spectral Doppler scan of the anterior tibial artery in the upper calf level also shows a normal triphasic pattern. Abnormal increase in reverse flow (negative flow in early diastolic phase) suggests increased distal resistance from stenosis.*

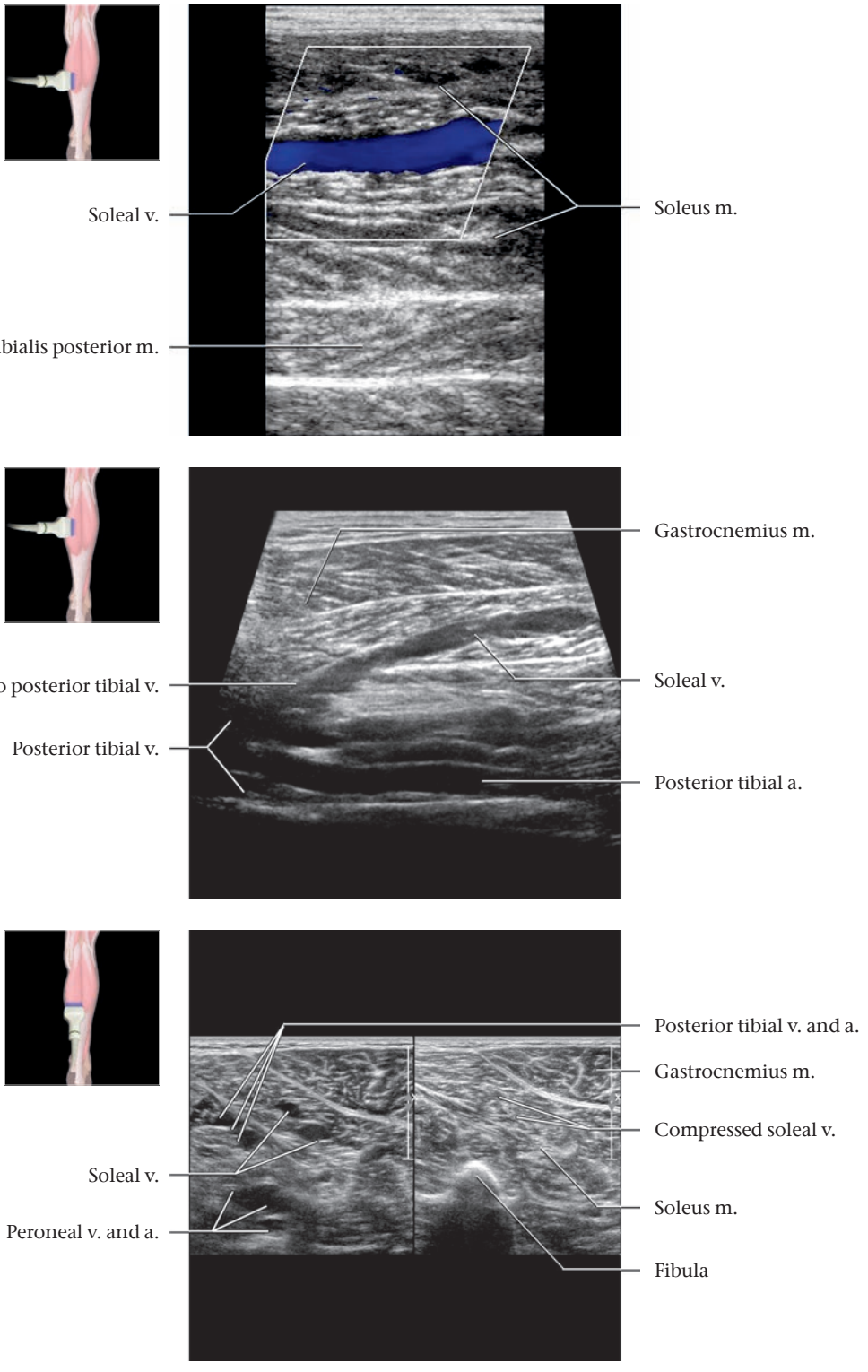
SPECTRAL DOPPLER OF LEG VEINS



(Top) *Oblique coronal spectral Doppler scan of the posterior tibial vein shows absence of spontaneous flow at rest (left 1/2 of the spectral trace). After augmentation (squeezing calf muscles distal to transducer), a surge of blood flow toward the trunk (negative values) can be demonstrated and indicates luminal patency.* ***(Middle)*** *Oblique coronal spectral Doppler scan of the peroneal vein before and after augmentation shows a similar sudden surge of blood flow.* ***(Bottom)*** *Oblique coronal spectral Doppler scan of the anterior tibial vein demonstrates slow spontaneous flow at rest. After augmentation, a sustained surge of flow is demonstrated.*

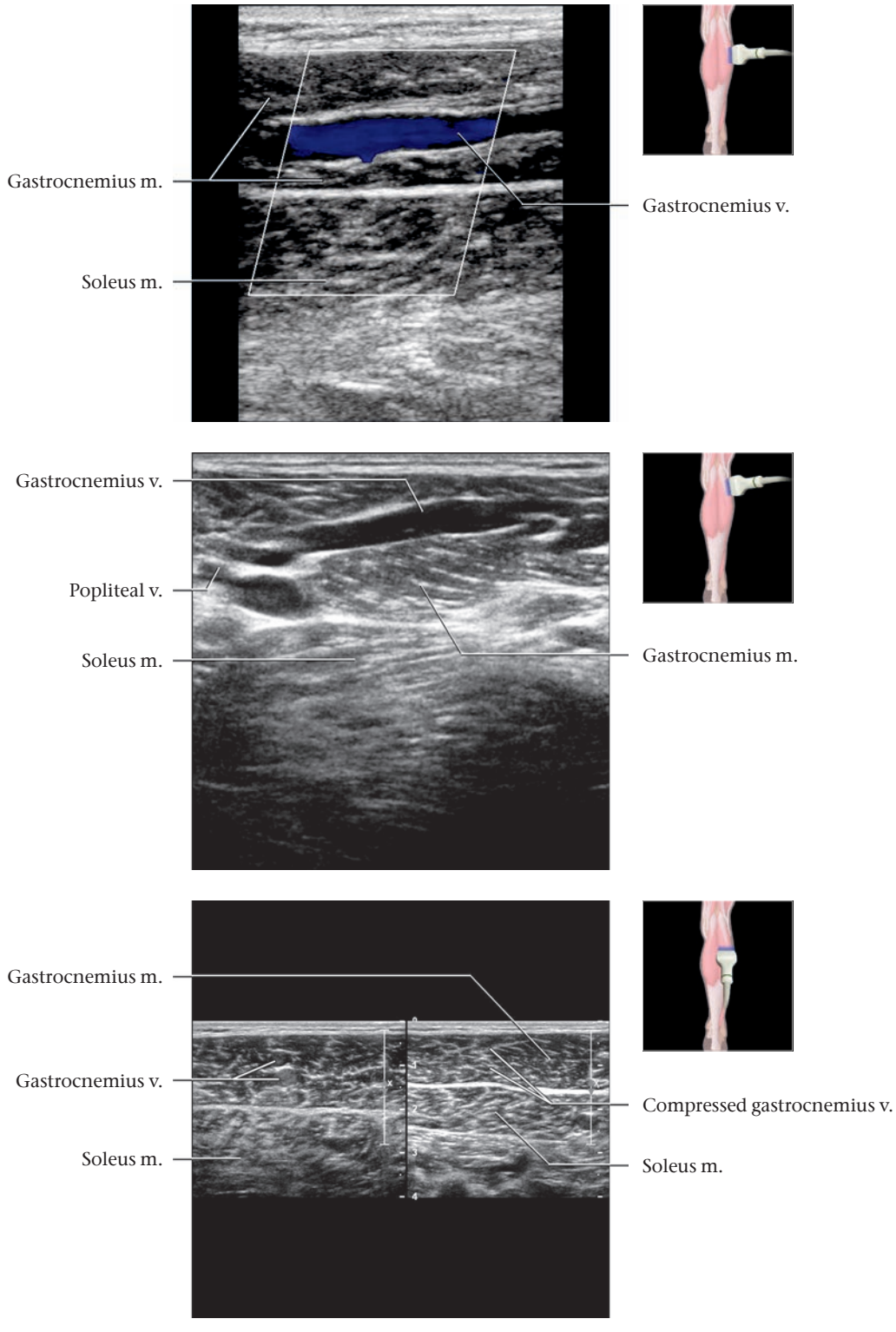
LEG VESSELS

SOLEAL VEINS



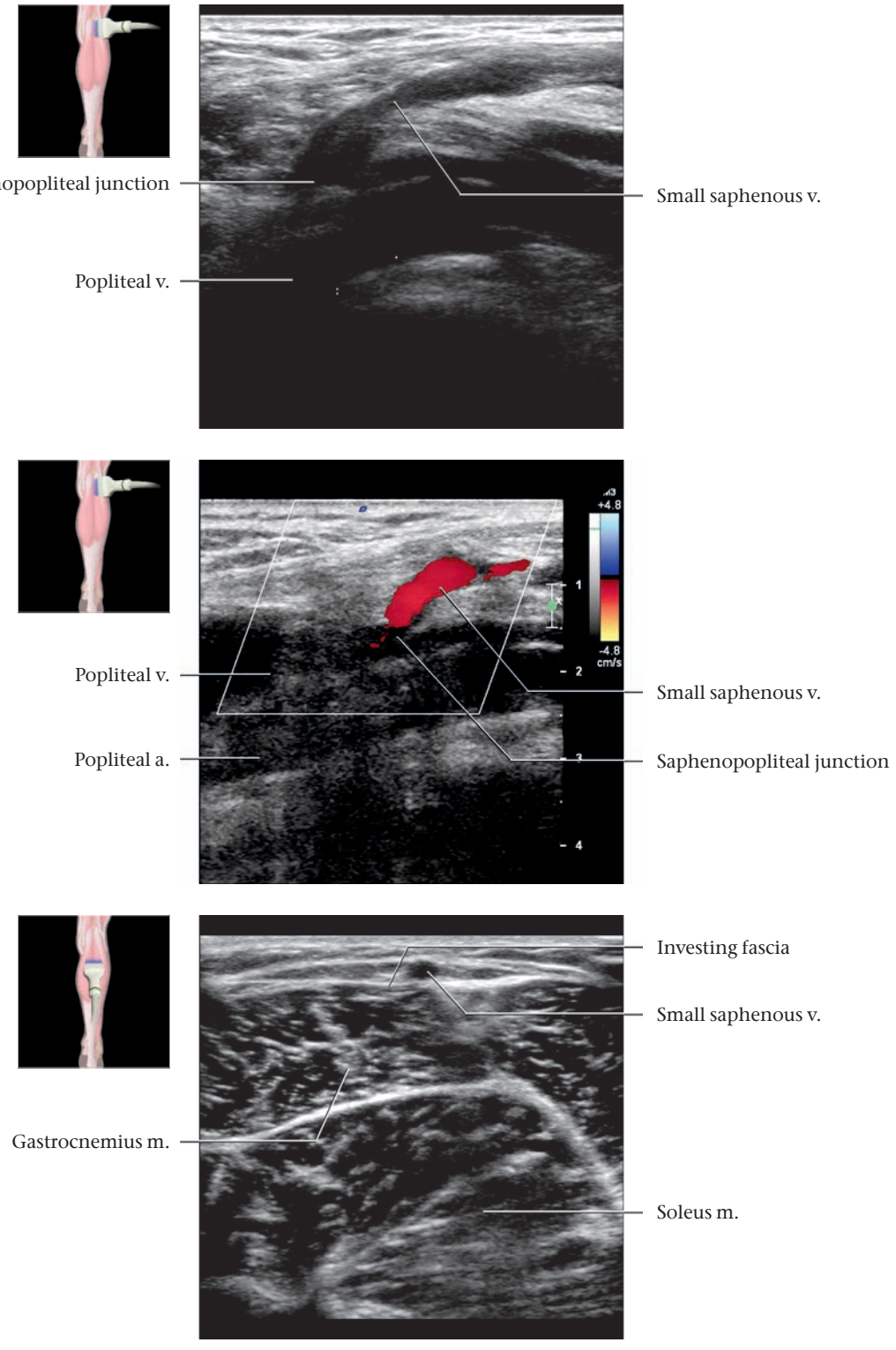
(Top) *Oblique sagittal color Doppler scan shows the posterior compartment in the midcalf level. The soleal vein shows complete color filling of its lumen indicating the absence of thrombus. Soleal veins are the most common veins to develop thrombosis and should be assessed when scanning for deep venous thrombosis.* ***(Middle)*** *Oblique sagittal scan of the posterior compartment shows the soleal vein running proximally and joining the posterior tibial vein. This pathway allows a soleal vein thrombus to extend into the posterior tibial vein and propagate proximally.* ***(Bottom)*** *Dual transverse images show the posterior compartment using a medial approach, before (left image) and during (right image) firm transducer compression. The soleal veins are completely compressed by transducer pressure, indicating an absence of thrombus.*

GASTROCNEMIUS VEINS



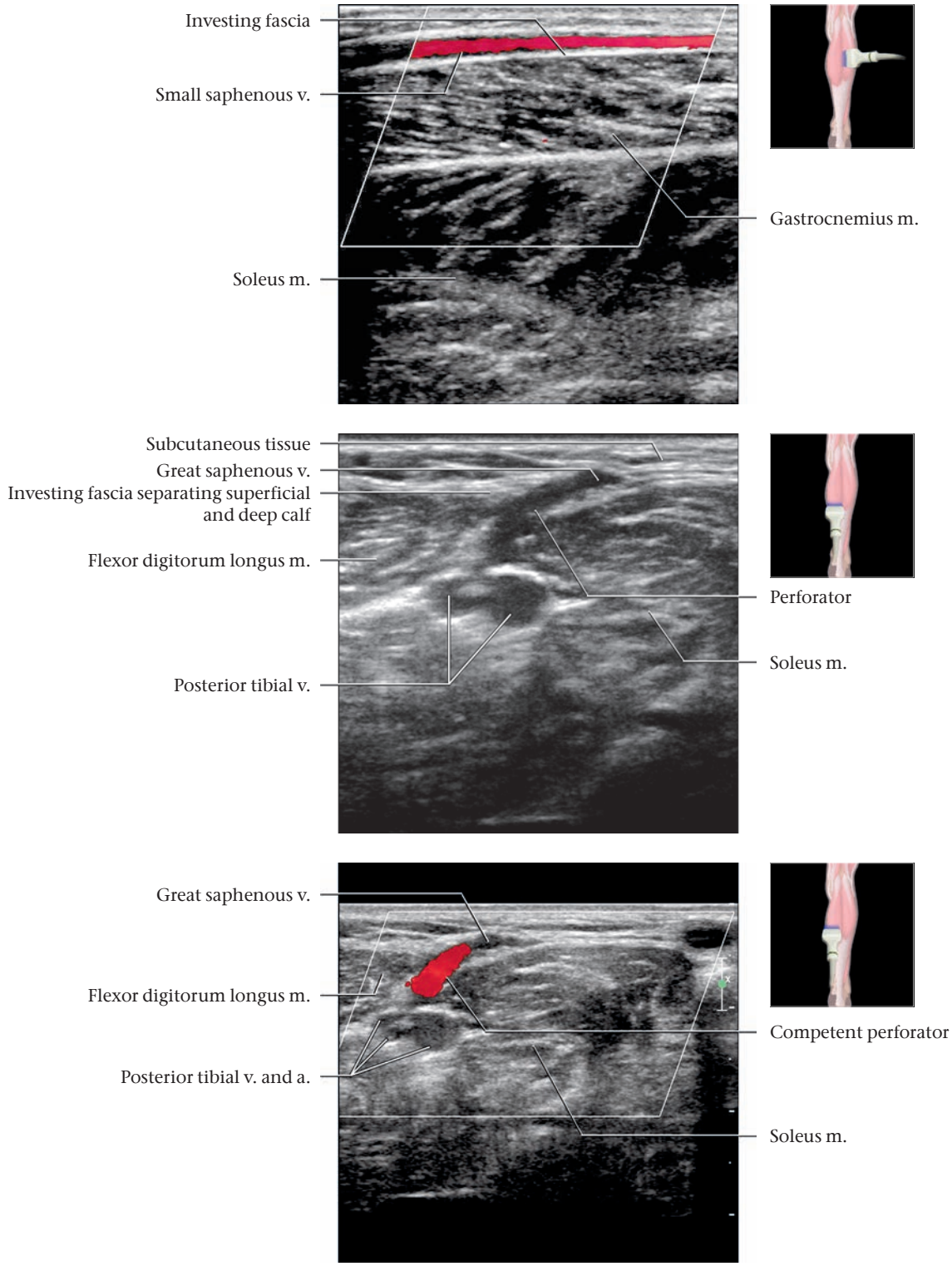
(Top) *Oblique sagittal color Doppler scan shows the posterior leg compartment. The gastrocnemius vein shows complete color filling indicating absence of thrombus. The gastrocnemius veins are the 2nd most common site for venous thrombosis.* ***(Middle)*** *Oblique sagittal scan of the posterior compartment of the upper calf shows the gastrocnemius vein joining the popliteal vein, allowing a gastrocnemius vein thrombus to extend proximally to the popliteal vein.* ***(Bottom)*** *Dual transverse images show gastrocnemius veins before (left image) and during (right image) compression . The gastrocnemius veins are completely compressed during compression, indicating an absence of thrombus. Compression is regarded as the most reliable technique to rule out venous thrombosis.*

SMALL SAPHENOUS VEIN



(Top) *Sagittal scan shows central popliteal fossa. The small saphenous vein running from the lateral surface of the calf turns medially and penetrates the popliteal fascia to drain into the popliteal vein. Varicose veins arise as a result of reflux and stasis due to incompetent valves. Varicose veins on the lateral side of the calf suggest an incompetent small saphenous system.* ***(Middle)*** *Sagittal color Doppler scan shows the central popliteal fossa with augmentation. Flow toward the popliteal vein (red) is demonstrated at the saphenopopliteal junction. Reverse flow into the small saphenous vein would suggest valvular incompetence.* ***(Bottom)*** *Transverse scan shows the posterior surface of the upper calf. The small saphenous vein is sandwiched between 2 layers of investing fascia. Minimal probe pressure is required to avoid inadvertent compression of the small saphenous vein.*

GREAT SAPHENOUS VEINS



(Top) *Sagittal color Doppler scan shows upper midcalf with augmentation. The complete filling of the venous lumen of the small saphenous vein is demonstrated, indicating the absence of a superficial vein thrombus. If flow toward the trunk is demonstrated, valvular incompetence can be excluded.* ***(Middle)*** *Transverse scan shows the medial aspect of the lower 1/3 of the calf. A perforator arising from the great saphenous vein is seen penetrating through the investing fascia to join the posterior tibial vein.* ***(Bottom)*** *Transverse color Doppler scan shows the medial aspect of the lower 1/3 of the calf. With augmentation, color filling of the perforator lumen is demonstrated in the perforator between the great saphenous vein and the posterior tibial vein, indicating patency of vessel. If flow toward the posterior tibial vein can be documented on Doppler study, incompetence can be excluded.*

LEG NERVES

GROSS ANATOMY

Sciatic Nerve

- Actually 2 nerves (common peroneal and tibial) bound together

Common Peroneal Nerve

- Smaller of 2 terminal divisions of sciatic nerve
- Arises from dorsal divisions of sacral plexus (L4, L5, S1, S2)
- Separates from tibial nerve midthigh, at superior angle of popliteal fossa, runs downwards laterally along medial border of biceps femoris muscle and tendon
- Leaves popliteal fossa by crossing plantaris and lateral head of gastrocnemius, passes posterior and superficial to head of fibula
- Curves anteriorly over posterior aspect of head of fibula
- Winds around lateral surface of fibular neck
  - Location at fibular head/neck puts peroneal nerve at risk in several clinical situations
    - Fibular neck fracture may result in foot drop
    - Realignment during correction of chronic knee valgus deformity may stretch nerve
- Ends between lateral side of neck of fibula and peroneus longus by dividing into 3 terminal branches
  - **Recurrent articular branch**
    - To proximal tibiofibular joint
    - Occasionally acts as conduit for intraneural transmission of ganglion arising from joint
  - **Deep peroneal nerve**
    - Arises on lateral side of neck of fibula, under peroneus longus
    - Pierces anterior intermuscular septum and extensor digitorum longus to enter anterior compartment
    - Extends down to ankle between tibialis anterior and long extensors
    - Near ankle, crossed by extensor hallucis and passes to ankle midway between malleoli
    - Muscular branches to anterior compartment and articular branch to ankle joint
    - Deep peroneal nerve crosses over to lateral side of dorsalis pedis artery at ankle joint
    - Medial and lateral terminal branches to dorsum of foot
    - Medial is main terminal branch and travels distally just medial to dorsalis pedis artery
  - **Superficial peroneal nerve**
    - Descends in substance of peroneus longus until it reaches peroneus brevis
    - Passes obliquely over anterior border of brevis and descends in groove between peroneus brevis and extensor digitorum longus
    - In distal 1/3 of leg, pierces deep fascia and divides into medial and lateral sensory branches to foot

Tibial Nerve

- Arises from ventral surface of sacral plexus
- Runs roughly along central axis of popliteal fossa
- Descends under fascial septum, which separates deep and superficial posterior muscle compartments
- In upper 2/3, lies on fascia of tibialis posterior and on flexor digitorum longus
- In lower 1/3, located midway between Achilles tendon and medial border of tibia
- Crosses posterior surfaces of tibia and ankle joint
- Posterior tibial vessels run with it, crossing in front of it from lateral to medial side
- At ankle, under flexor retinaculum, divides into lateral and medial plantar nerves
  - 1st branch of lateral plantar nerve is the inferior calcaneal nerve (Baxter nerve)
    - Since this nerve supplies calcaneal periosteum, neuritis of this nerve can simulate plantar fasciitis
  - Medial plantar nerve can become compressed between navicular tuberosity and abductor hallucis muscle belly (Jogger's foot)

Saphenous Nerve

- Longest branch of femoral nerve, arising 2 cm below inguinal ligament and descending via adductor canal
- Passes posterior to sartorius, descends posteromedial to knee where it pierces deep fascia
- In leg, accompanies great saphenous vein

Sural Nerve

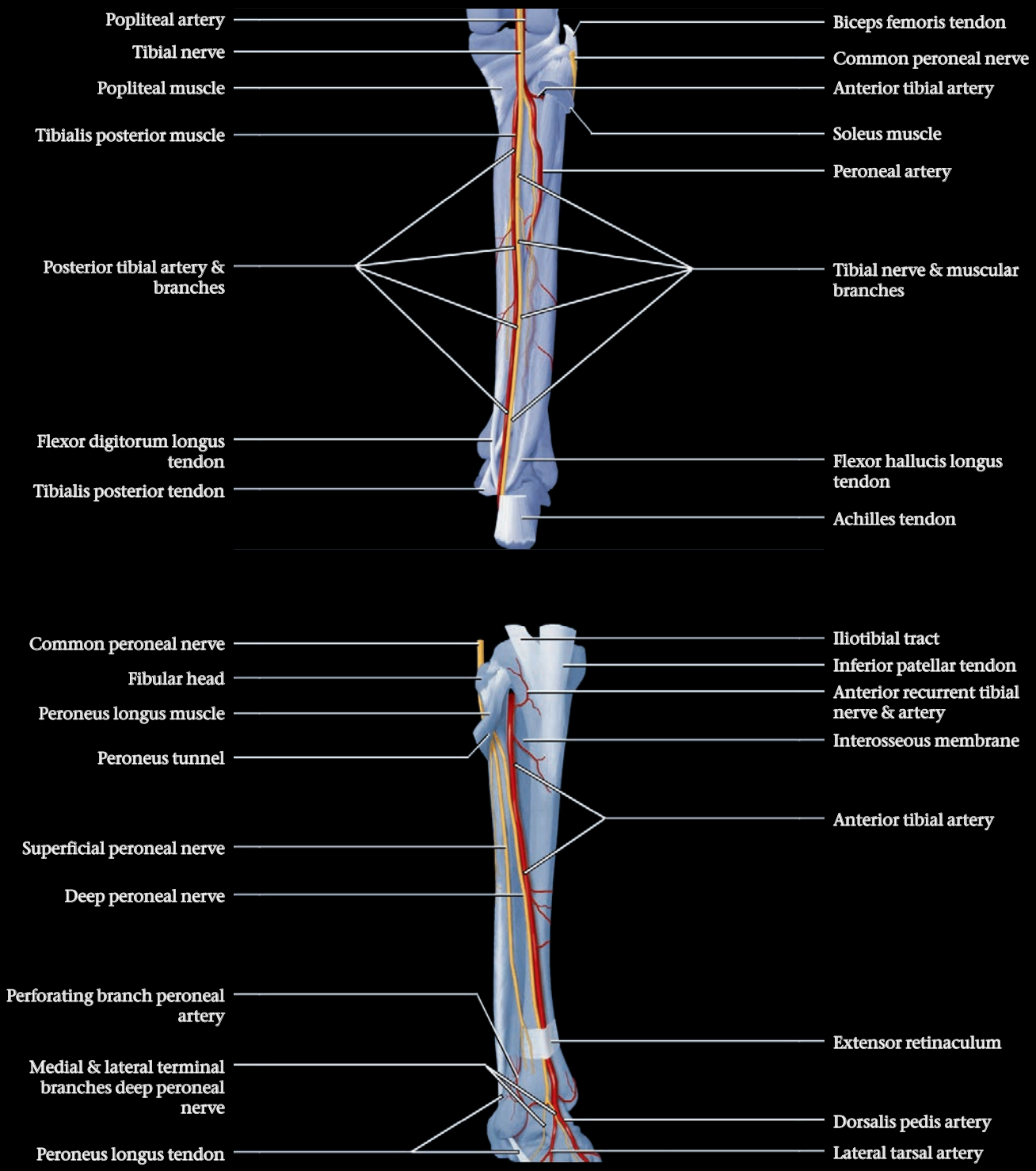
- Purely sensory nerve that arises in popliteal fossa from tibial nerve
- Descends between 2 heads of gastrocnemius
- Pierces deep fascia midway between knee and ankle
- Courses superficial and posterior to peroneal tendons
- Accompanies small saphenous vein to lateral border of foot

ANATOMY IMAGING ISSUES

Imaging Approaches

- Ultrasound
  - Use high-frequency transducers to assess nerves
  - Neural signature on ultrasound
    - Short axis: Uniformly dispersed hypoechoic dots (nerve fascicles) separated by hyperechoic epineurium
    - Long axis: Parallel hypoechoic tracts of uniform caliber
    - Overall gain control and focus settings may have to be optimized for ultrasound to demonstrate nerve well
    - Anisotropy artifact may affect scanning, especially in short axis; tilting transducer during scanning helps achieve best view
    - Distortion of this uniform appearance suggests pathology
  - Trace medium-sized nerves by following their course as they branch from their parent
  - Small (1-2 mm) nerves are difficult to identify and location may only be inferred by adjacent vessels
- MR
  - Also suffers from inability to detect small nerves
  - Use of superficial small field of view coils may improve resolution

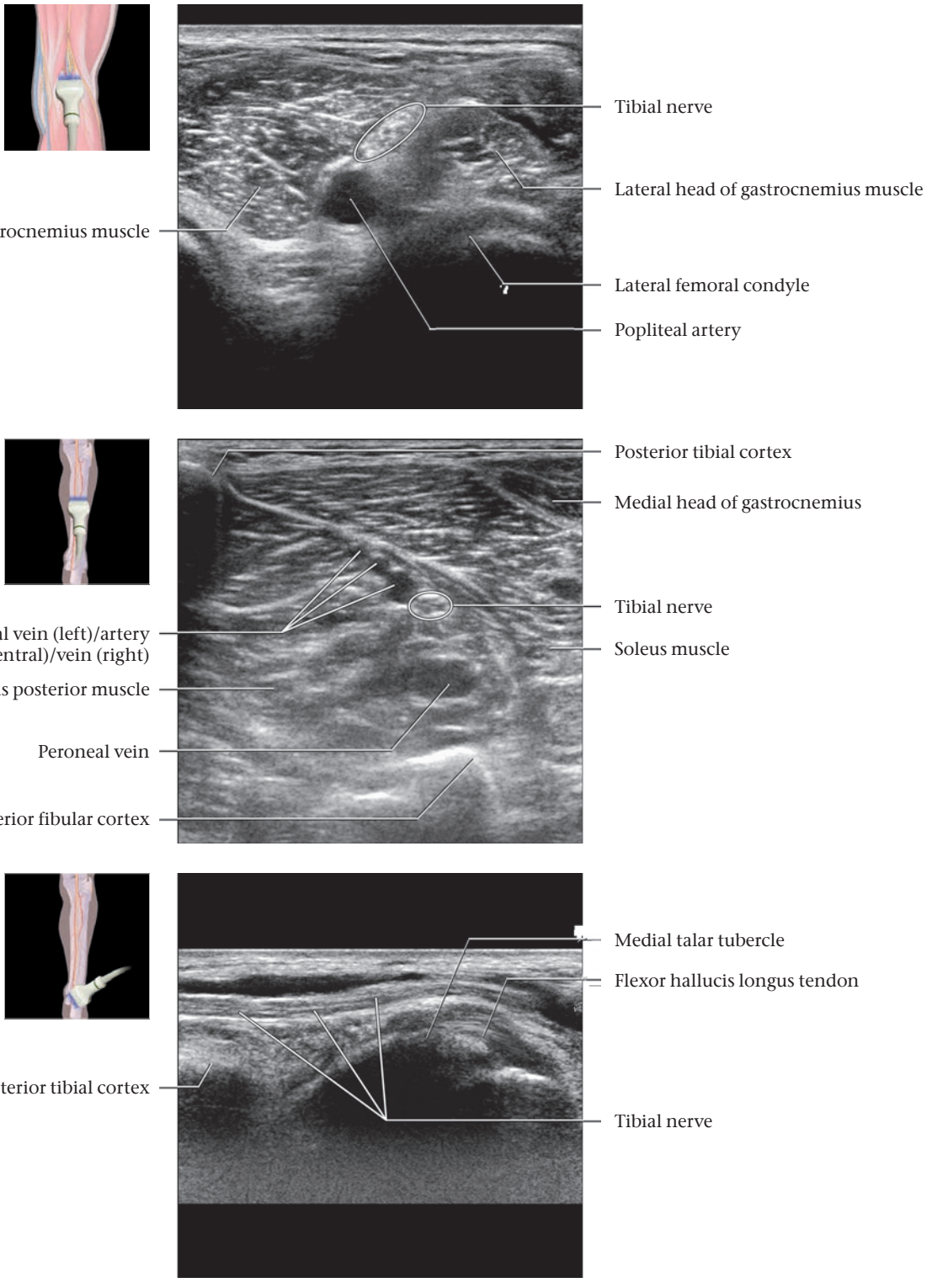
GRAPHICS, ANTERIOR AND POSTERIOR LEG NERVES



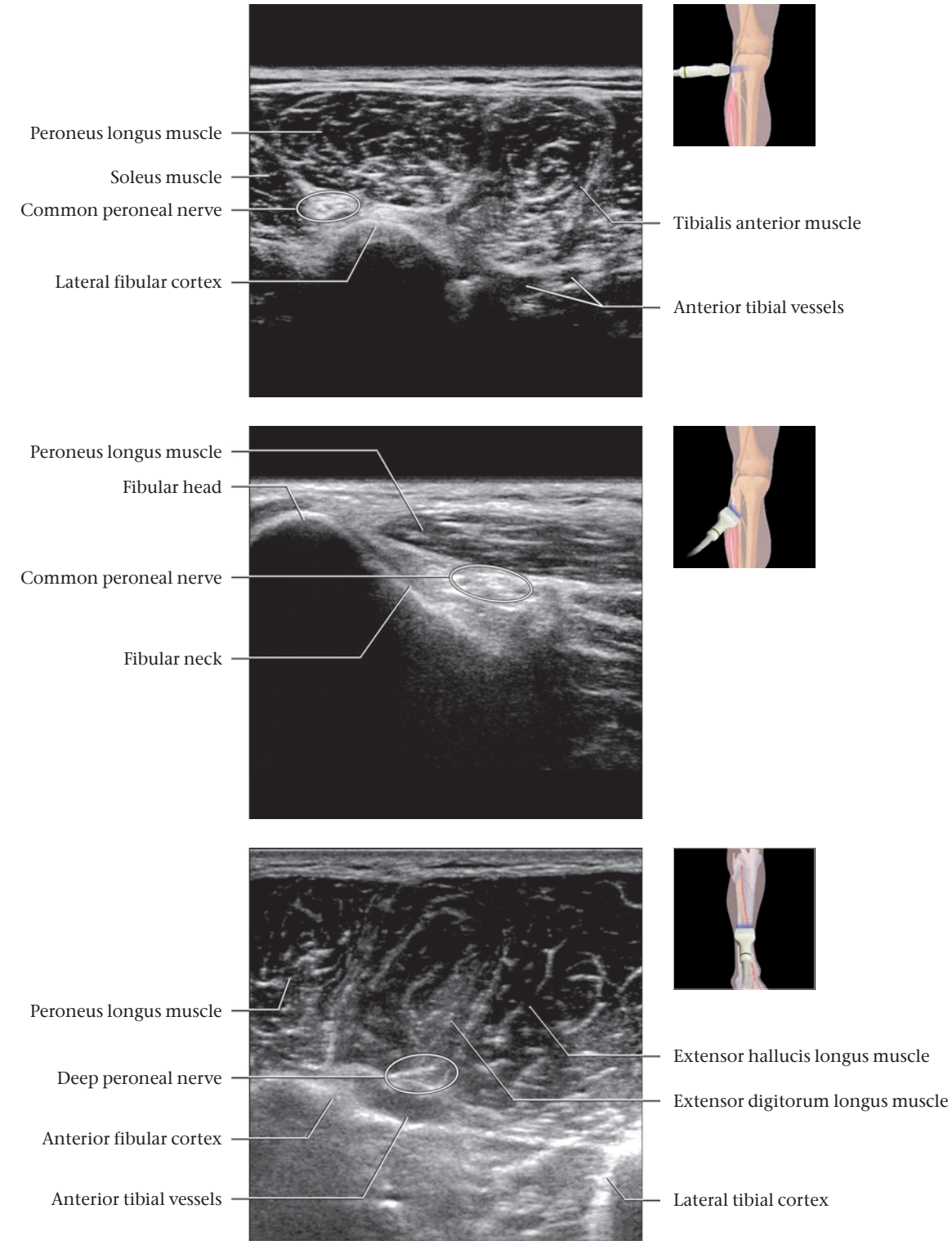
(Top) *Graphic shows posterior leg nerves and arteries. The sciatic nerve divides into common peroneal and tibial branches. The common peroneal nerve then follows the biceps femoris around the lateral fibular neck. The tibial nerve descends between the deep and superficial posterior leg muscles, paralleling the posterior tibial artery.* ***(Bottom)*** *Graphic of the anterior leg shows the common peroneal nerve extending through the peroneal tunnel (between the peroneus longus tendon and the fibular neck), branching into deep and superficial components. Both have muscular branches along their length; the deep peroneal nerve parallels the anterior tibial artery and terminates in the medial and lateral branches to the dorsum of the foot and ankle, respectively.*

LEG NERVES

TIBIAL NERVE



(Top) *Transverse scan shows the lower aspect of the popliteal fossa. The tibial nerve demonstrates the typical neural signature of small black dots within a bright matrix. It lies superficial to the popliteal artery.* ***(Middle)*** *Further inferiorly, at the level of the midcalf, the tibial nerve is deep to the soleus muscle and lies lateral to the posterior tibial vessels. Notice that even at this depth the neural signature is still visible.* ***(Bottom)*** *Sagittal scan shows the posterior aspect of the medial ankle. The longitudinal neural signature of the tibial nerve is well shown here with parallel hypoechoic tracts, which are roughly uniform in size. Contrast this to the more densely packed appearance of tendons.*



(Top) *Transverse scan of the head of fibula shows the common peroneal nerve running along the posteromedial aspect of the peroneus longus muscle. Superior to this, the nerve is covered by the biceps femoris muscle and tendon.* ***(Middle)*** *Coronal scan of the fibular neck shows the common peroneal nerve passing deep to the peroneus longus muscle. The nerve will then enter the anterior compartment.* ***(Bottom)*** *Transverse scan shows the anterior compartment at the midleg level. The deep peroneal nerve runs anterior to the anterior tibial vessels deep in this compartment.*

ANKLE

TERMINOLOGY

Abbreviations

- Artery (a.)
- Ligament (l.)
- Muscle (m.)
- Tendon (t.)
- Vein (v.)

GROSS ANATOMY

Osseous Anatomy

- **Ankle (talocrural) joint**
  - Tibia, fibula, and talus form synovial joint
  - Supported by lateral and medial collateral ligaments
  - Mainly uniaxial hinge joint, dorsiflexion, plantar flexion, also dynamic shift of axis of rotation during dorsiflexion and plantar flexion
- **Distal tibiofibular joint**
  - Fibrous joint
  - Supported by syndesmotic ligaments
  - Synovial recess from ankle joint extends into joint
  - May have articular cartilage far distally
  - Minimal stretch ("give") during dorsiflexion: Allows increase in malleolar gap and slight fibular lateral rotation

Ligaments

- 3 sets bind ankle: Distal tibiofibular syndesmotic complex, lateral collateral ligaments, and deltoid ligaments
- **4 tibiofibular syndesmotic ligaments**
  - **Anterior and posterior tibiofibular ligaments**
    - Extend obliquely between anterior and posterior tibial and fibular tubercles, respectively
    - Distal anterior tibiofibular ligament: Bassett ligament
  - **Inferior transverse ligament**: Distal part of posterior tibiofibular ligament
  - **Interosseous ligament**: Distal thickening of syndesmotic membrane
- **3 lateral collateral ligaments**
  - **Anterior talofibular ligament**
    - Originates 1 cm proximal to lateral malleolar tip; inserts on talar neck
    - Stabilizes talus against anterior displacement, internal rotation, and inversion
    - Weakest, 1st to tear
  - **Calcaneofibular ligament**
    - Originates from lateral malleolar tip; inserts on calcaneal trochlear eminence
    - Deep to peroneal tendons
    - Lateral restraint of subtalar joint, often tears with anterior talofibular ligament
  - **Posterior talofibular ligament**
    - Extends from lateral malleolar fossa to lateral talar tubercle
    - Strongest, rarely tears
- **Deltoid ligament (medial collateral ligament)**
  - Fan-shaped, originates from anterior, apex, and posterior medial malleolus; inserts on talus, sustentaculum tali, spring ligament, and navicular
  - Deep: Posterior and anterior tibiotalar bands
  - Superficial: Tibiocalcaneal, tibiospring, tibionavicular, and posterior tibiotalar (variable) bands
- **Spring ligament (plantar calcaneonavicular ligament)**
  - Binds calcaneus to navicular, 3 components
    - Superomedial = **origin**: Sustentaculum tali; **insertion**: Superomedial navicular, tibiospring band of deltoid
    - Medioplantar oblique = **origin**: Calcaneal coronoid fossa; **insertion**: Plantar navicular
    - Inferoplantar longitudinal = **origin**: Coronoid fossa; **insertion**: Navicular beak

Retinacula

- Focal thickening of deep fascia
- Prevents bowstringing, binds tendons down
- **Superior extensor retinaculum**
  - A few cm above ankle joint
  - Attaches to anterior fibula laterally, tibia medially
  - Proximally continues with fascia cruris
  - Distally attaches to inferior extensor retinaculum
  - Binds down anterior compartment muscles
- **Inferior extensor retinaculum**
  - At ankle joint, Y-shaped, stem laterally, proximal and distal bands medially
  - Stem attaches laterally to upper calcaneus
    - Loops around extensor tendons
    - Roots extend into sinus tarsi
  - Proximal medial band has deep and superficial layers, loop around extensor hallus longus tendon and occasionally tibialis anterior tendon
  - Distal medial band superficial to extensor hallucis longus and tibialis anterior tendons
    - Attaches to plantar aponeurosis
  - Dorsalis pedis vessels, deep peroneal nerve: Deep to all layers of inferior extensor retinaculum
- **Flexor retinaculum**
  - Attaches to medial malleolus
  - Proximally continuous with deep fascia of leg
  - Distally continuous with plantar aponeurosis
  - Abductor hallucis partly attached to it
  - Binds deep flexor tendons to tibial and calcaneal grooves
  - Lateral border of tarsal tunnel
- **Superior peroneal retinaculum**
  - Origin: Lateral malleolus, insertions vary, most commonly to deep fascia of leg and calcaneus
  - Binds peroneal tendons into retrofibular groove
- **Inferior peroneal retinaculum**
  - Continuous with inferior extensor retinaculum
  - Inserts on lateral calcaneus, peroneal tubercle (trochlea)
  - Binds peroneus brevis, peroneus longus tendons to calcaneus

Tendons

- Muscles discussed in greater detail in leg module
- **Anterior (extensor) compartment**
  - **Tibialis anterior tendon**
    - Most medial and largest tendon in anterior compartment
    - Inserts on medial cuneiform, base of 1st metatarsal
    - Dorsiflexes ankle, inverts foot, tightens plantar aponeurosis

- Supports medial longitudinal arch during walking
- **Extensor hallucis longus tendon**
  - Inserts on dorsal base of 1st distal phalanx
  - Extends 1st phalanges, dorsiflexes foot
- **Extensor digitorum longus tendon**
  - Divides into 4 slips on dorsum of foot
  - Slips receive tendinous contributions from extensor digitorum brevis, lumbricals, and interosseous muscles
  - Each slip divides into 3: Central slip inserts on dorsal base of middle phalanx and 2 collateral slips, which reunite and insert on bases of 2nd-5th distal phalanges
  - Dorsiflexes ankle, extends toes, tightens plantar aponeurosis
- **Peroneus tertius tendon**
  - Typically part of extensor digitorum longus tendon
  - Inserts on dorsal base of 5th metatarsal

· **Lateral compartment**
- **Peroneus longus tendon**
  - Posterolateral to peroneus brevis tendon in retrofibular groove, deep to superior peroneal retinaculum
  - Proximally has common tendon sheath with peroneus brevis
  - Separates tendon sheath at sole of foot
  - Descends inferior to peroneal tubercle, deep to inferior peroneal retinaculum
  - Curves in cuboid groove deep to long plantar ligament
  - Inserts on plantar base of 1st metatarsal, medial cuneiform
  - Plantarflexes ankle, everts foot, supports longitudinal and transverse arches during walking
  - Os peroneum is in ~ 20% of individuals
- **Peroneus brevis tendon**
  - Anteromedial to peroneus longus tendon in retrofibular groove, deep to superior peroneal retinaculum
  - Descends superior to peroneal tubercle of calcaneus, deep to inferior peroneal retinaculum
  - Inserts into base of 5th metatarsal
  - Everts foot, limits foot inversion

· **Superficial posterior compartment**
- **Achilles tendon**
  - Largest and strongest tendon in body
  - Commonest tendon to rupture
  - Conjoint tendon of medial and lateral gastrocnemius and soleus muscles
  - ~ 15 cm long
  - Lacks tendon sheath partially enclosed by paratenon
  - Inserts into posterior calcaneal tuberosity
  - Crescent-shaped insertion with medial and lateral projections
  - Retrocalcaneal bursa between distal tendon and calcaneal tuberosity
  - Main plantarflexor of ankle, foot
  - Midsection of Achilles tendon is supplied by peroneal artery
  - Proximal and distal portions supplied by posterior tibial artery

· **Plantaris tendon**
- Vestigial, slender tendon, medial to Achilles tendon
- Inserts on or medial to Achilles tendon

· **Deep posterior (flexor) compartment**
- **Tibialis posterior tendon**
  - Crosses flexor digitorum longus tendon above ankle joint to become most posteromedial tendon
  - Shares tibial groove with flexor digitorum longus tendon
  - Inserts on navicular tuberosity, cuneiforms, sustentaculum tali, bases of 2nd-4th metatarsals
  - Main invertor of foot, aids in plantar flexion
  - Supports medial longitudinal arch
- **Flexor digitorum longus tendon**
  - Lateral to tibialis posterior tendon in tibial groove
  - Crosses flexor hallucis longus tendon at knot of Henry (where there is also an exchange of tendon fibers at this crossing of 2 tendons)
  - Divides into 4 slips, which give origin to lumbricals
  - Slips pass through openings in corresponding tendons of flexor digitorum brevis
  - Slips insert on bases of 2nd-5th distal phalanges
  - Flexes distal phalanges, assists in plantar flexion of ankle
  - When foot on ground: Maintains pads of toes on ground
  - When foot off ground: Plantar flexes 2nd-5th phalanges, aids in maintaining longitudinal arches
- **Flexor hallucis longus tendon**
  - Passes 3 fibroosseous tunnels: (1) Between medial and lateral talar tubercles, (2) under sustentaculum tali, and (3) between 1st medial and lateral sesamoids
  - Crosses and sends slip to flexor digitorum longus at knot of Henry
  - Inserts on base of 1st distal phalanx
  - When foot on ground: Maintains pad of 1st toe on ground
  - When foot off ground: Plantar flexes 1st phalanges, aids in maintaining medial longitudinal arch
  - Weak plantar flexor of ankle
  - Innervated by tibial nerve

ANATOMY IMAGING ISSUES

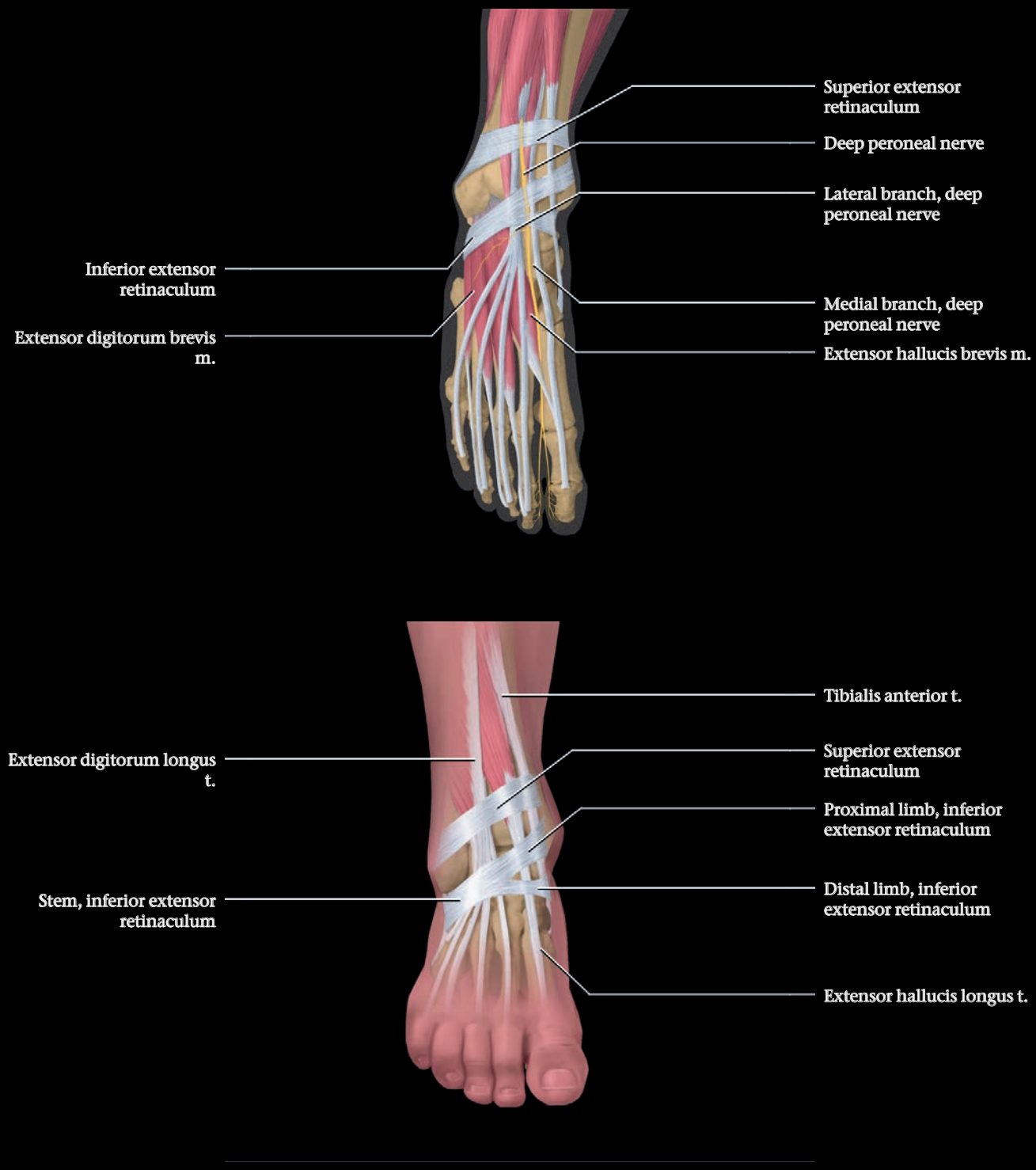
Imaging Recommendations

· **Ultrasound**
- Use ultrasound to assess tendon and ligamentous abnormalities aside from masses around ankle joint
- Ligaments and tendons need to be assessed in both long and short axis
- Since most structures run obliquely and tendons make acute turns around joint, a clear understanding of their relationships and associated bony landmarks is helpful

· **Computed tomography**
- Best for bony anatomy
- Superior to MR for detecting small avulsion fragments

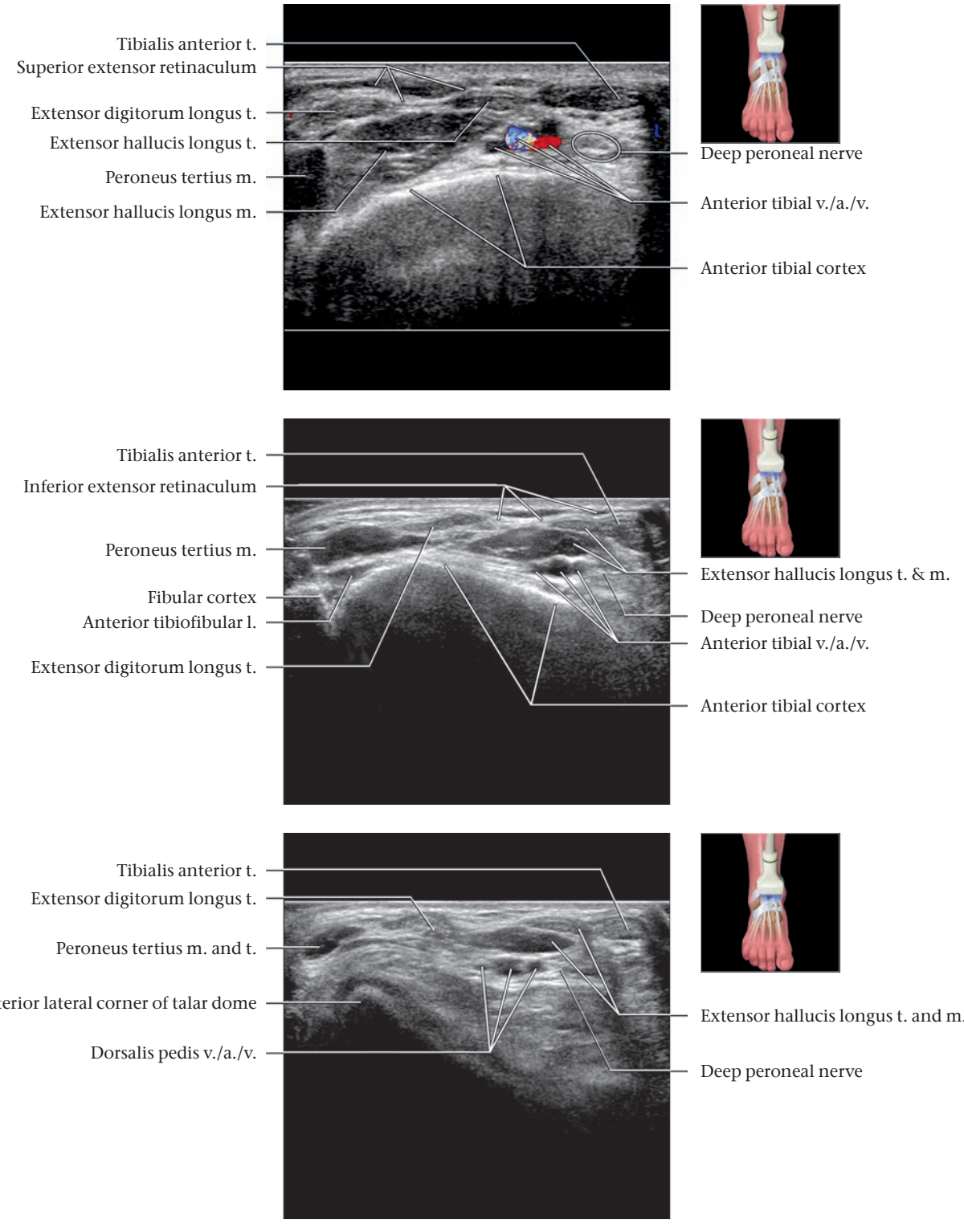
· **MR of ankle and hindfoot**
- Axials optimal for ankle tendons, ligaments
- Coronals useful for bones, cartilage, ankle, and sinus tarsi ligaments
- Sagittals optimal for Achilles tendon, bones, cartilage, sinus tarsi ligaments

GRAPHICS, ANTERIOR ANKLE



(Top) *The deep peroneal nerve travels deep to extensor retinacula in anterior tarsal tunnel, and gives a lateral motor branch to the extensor digitorum brevis muscle. The medial branch continues dorsal to talonavicular joint, middle cuneiform, and in between 1st & 2nd metatarsal to provide mostly sensory but some motor supply to 1st web space.* ***(Bottom)*** *The peroneus tertius and tibialis anterior tendon insert proximally, on the base of the 5th metatarsal and on the medial cuneiform and 1st metatarsal, respectively. The rest of the extensor tendons continue distally toward their insertion sites on the digits. The extensor tendons are held in place by the superior and inferior extensor retinacula.*

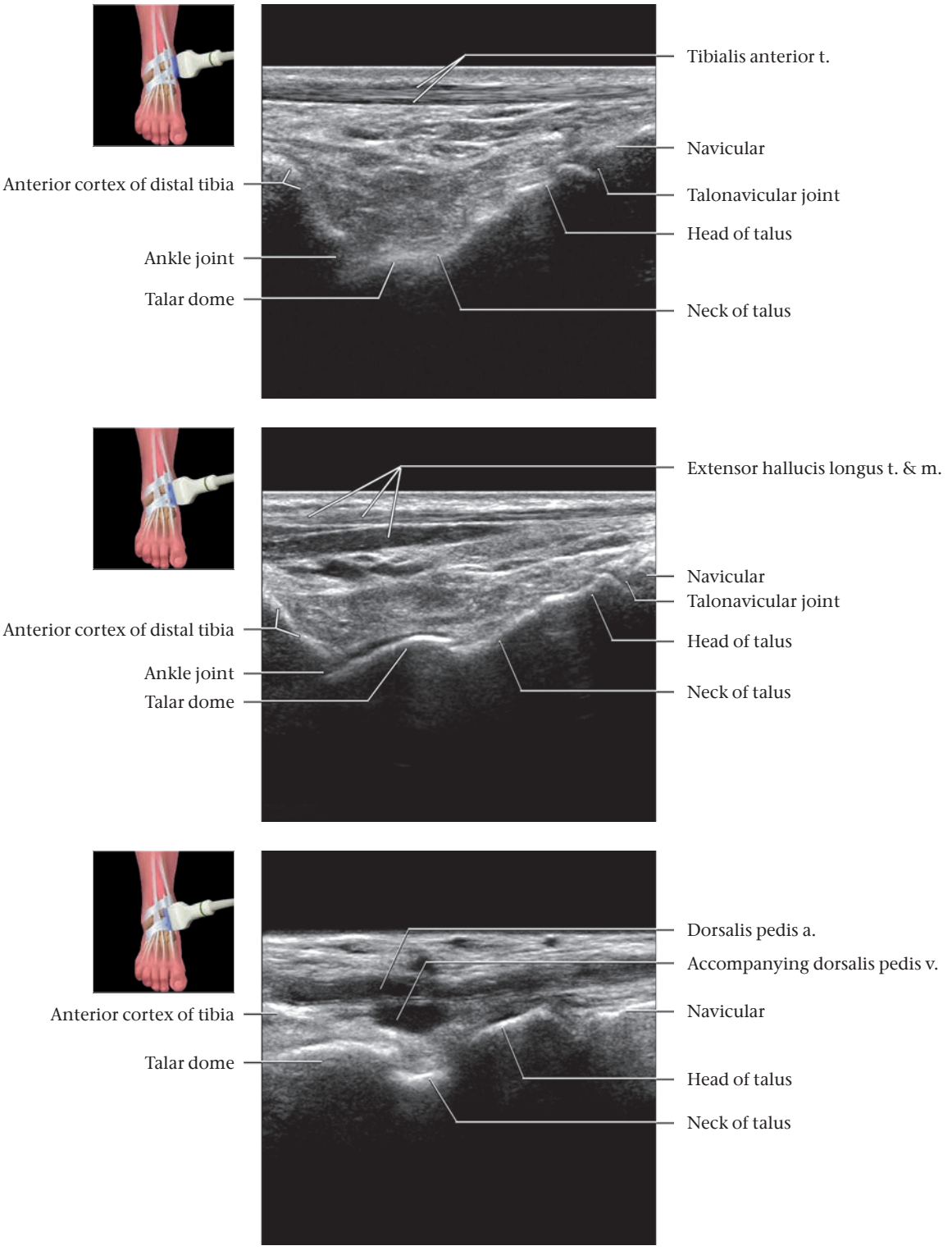
ANTERIOR ANKLE



(Top) *Anterior transverse color Doppler scan above level of the ankle joint is shown. The basic relationship of the main structures of the anterior ankle hold true here and down through the ankle joint. From medial to lateral, the structures are: Tibialis anterior, extensor hallucis longus, nerve AND vessels, and extensor digitorum longus (mnemonic: Tom, Harry, AND Dick).* ***(Middle)*** *Transverse scan of the ankle joint at the level of the anterior talofibular ligament is shown. The anterior talofibular ligament, like most ankle ligaments, runs an oblique course and therefore, may appear irregular or interrupted on a straight axial scan. This can be corrected by scanning obliquely along the long axis of the ligament.* ***(Bottom)*** *Transverse scan more inferiorly shows the asymmetrical soft tissue thickness anterior to the talus (thicker medially) due to different orientation axes of talus and foot.*

ANKLE

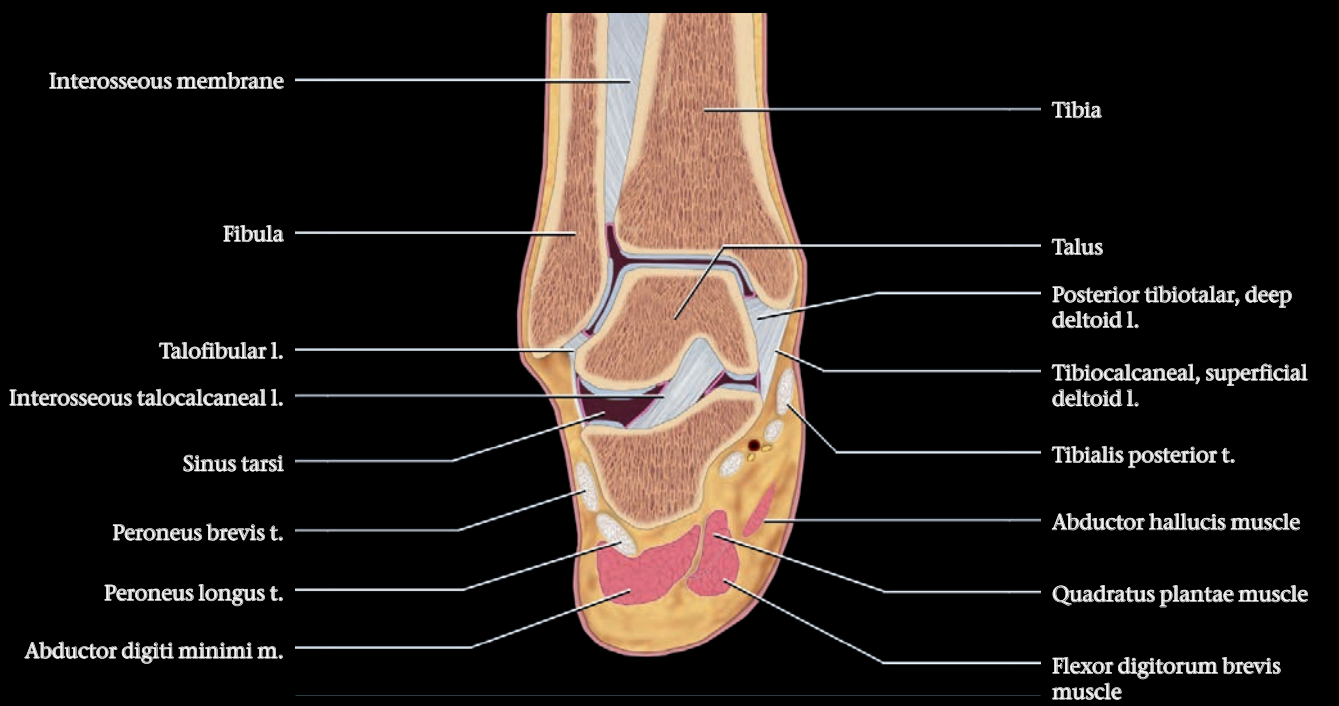
ANTERIOR ANKLE



(Top) *Longitudinal scan of the lateral aspect of the ankle shows the course of the tibialis anterior tendon. A thin hypoechoic synovial layer can be seen enveloping the tendon.* ***(Middle)*** *Slightly more laterally, sagittal scan shows the extensor hallucis longus tendon and muscle, the latter distinguishing it from the tibialis anterior tendon.* ***(Bottom)*** *Further laterally, the dorsalis pedis artery and the accompanying vein(s) come into view. At this point, the subcutaneous tissue is thinnest, a result of the transverse arch of the midfoot with the apex roughly coinciding with the site of this artery. This creates a shallow bony backing for palpating the artery.*

MEDIAL ANKLE



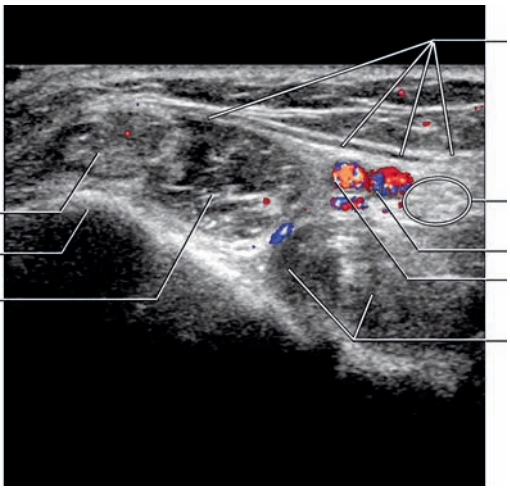


(Top) *Tarsal tunnel is seen accommodating the posterior tibial neurovascular bundle. The medial calcaneal nerve supplies skin of the medial heel. The medial plantar nerve supplies flexor hallucis brevis, abductor hallucis, flexor digitorum brevis, and 1st lumbrical. It carries sensation from medial 2/3 of the plantar foot. The lateral plantar nerve supplies all other plantar muscles including 2nd-4th lumbricals and all interossei, plus sensation from lateral 1/3 of mid and forefoot.* ***(Bottom)*** *Illustration of coronal section through the tibia, fibula, talus, and calcaneum shows the ankle ligaments. On the medial side, the medial malleolus is connected via the deep and superficial deltoid ligaments to the medial tarsal bones. The tibialis posterior tendon passes over the deltoid ligament as it curves below the medial malleolus. The talocalcaneal interosseous ligament, which has at least 4 discrete components, maintains apposition of the talus and calcaneus during hindfoot eversion and inversion.*

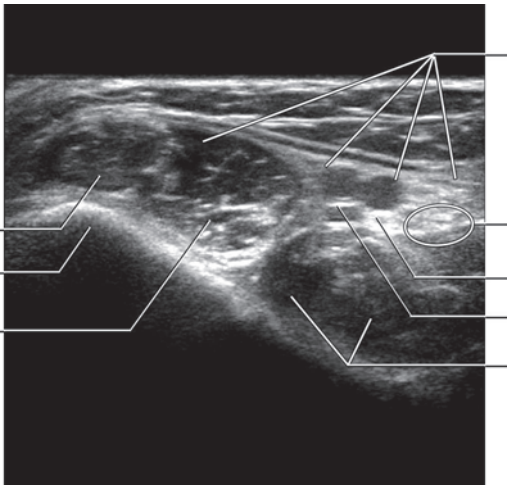
ANKLE

MEDIAL ANKLE

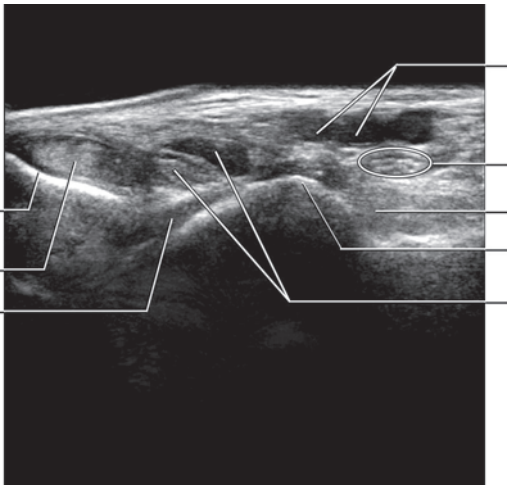






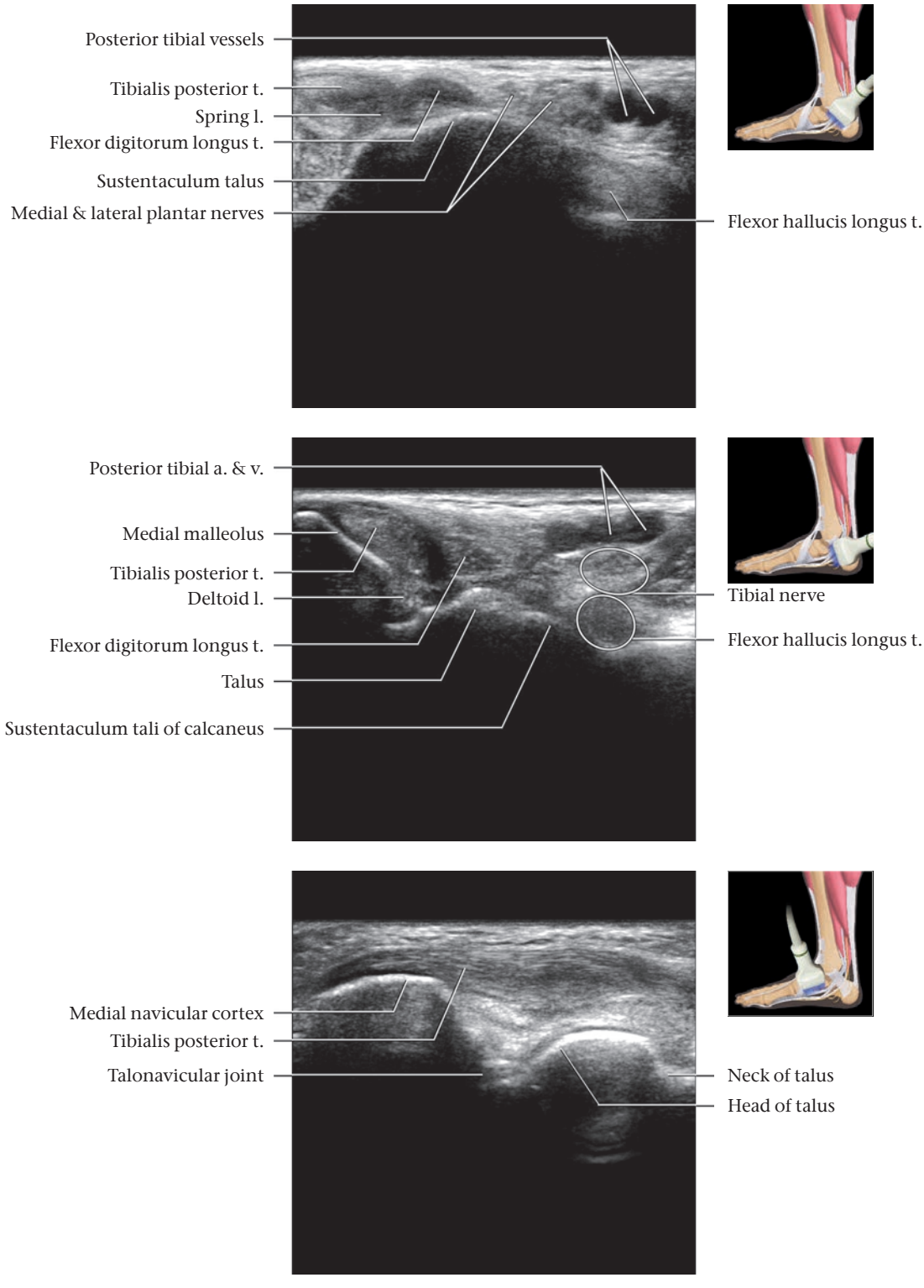






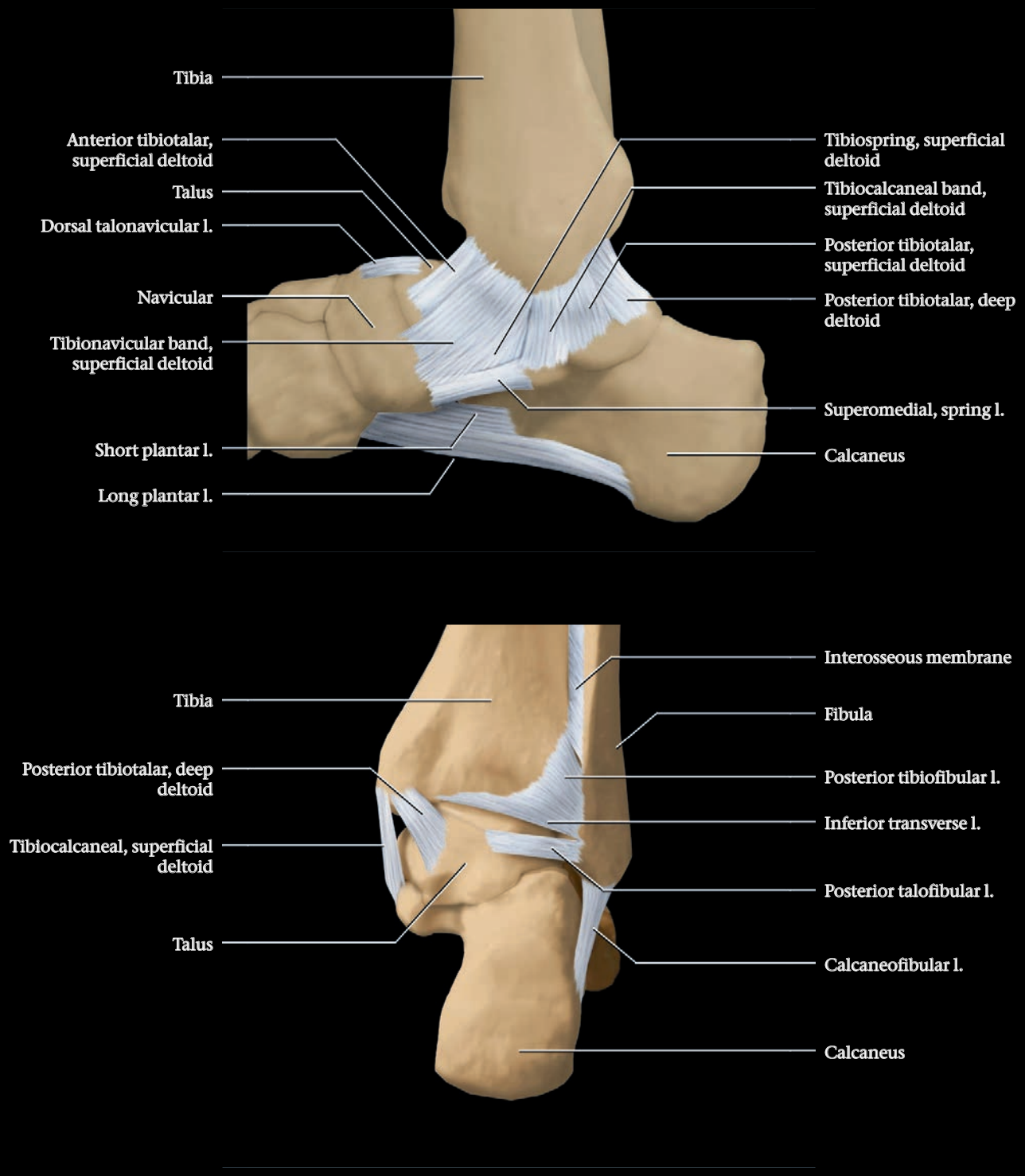
(Top) *Transverse color Doppler scan shows the posterior aspect of the distal tibia just above the medial malleolus. This area is held down by the flexor retinaculum and termed the tarsal tunnel. Within this tunnel are tibialis posterior, flexor digitorum longus, vessels AND nerve, and flexor hallucis longus (mnemonic: Tom, Dick, AND Harry).* ***(Middle)*** *Corresponding grayscale transverse scan just above the medial malleolus is shown. Image is less grainy without simultaneous color Doppler interrogation, and the nerve fibers (hypoechoic dots) give the typical neural signature.* ***(Bottom)*** *At the level of the talus, the tibial nerve moves anteriorly to run deep to the posterior tibial vessels and superficial to the flexor hallucis longus tendon. The flexor hallucis longus tendon runs in a groove on the posterior surface of the talus.*

MEDIAL ANKLE



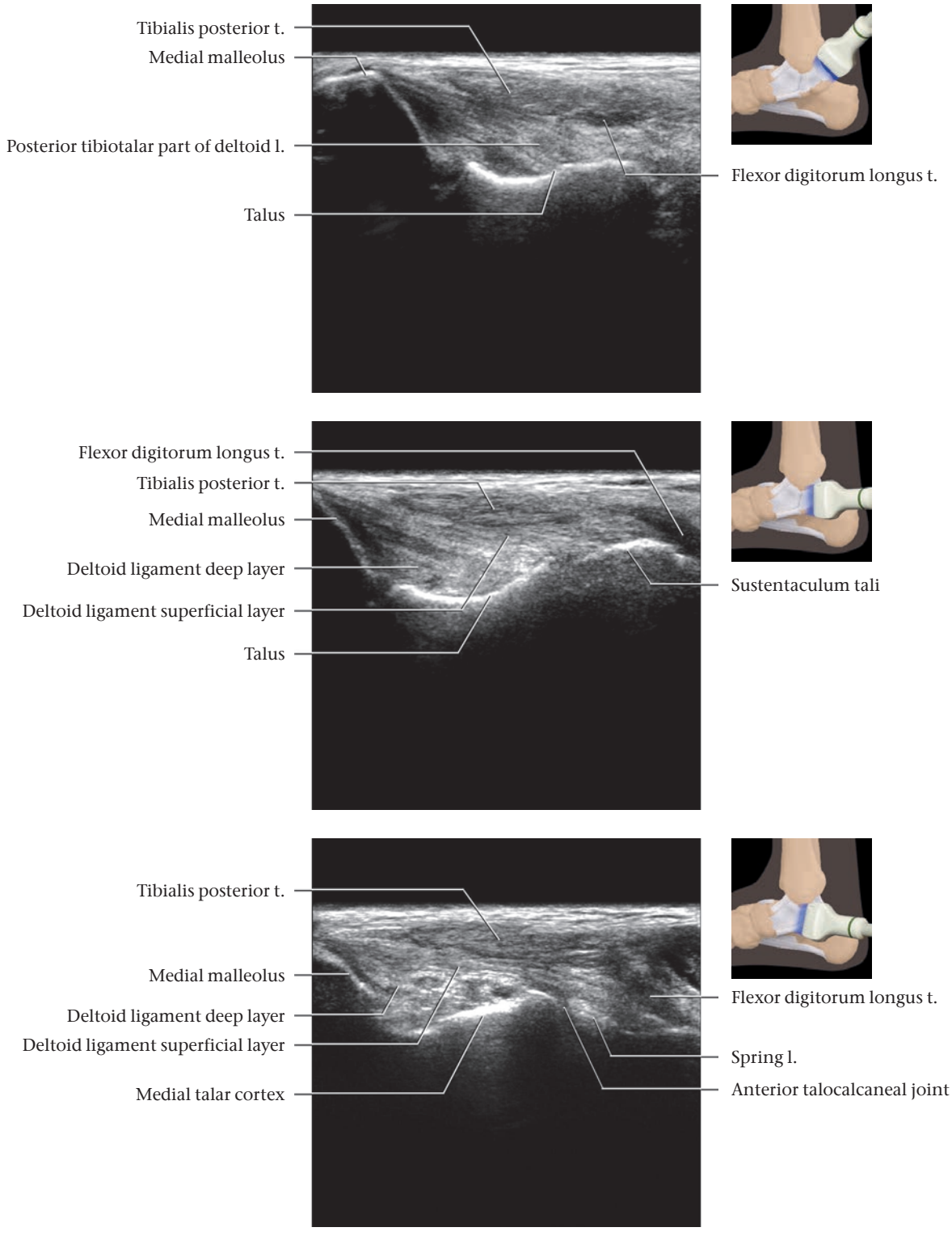
(Top) *More inferiorly, oblique transverse scan through the sustentaculum tali of the calcaneus shows that the mnemonic of Tom, Dick, AND Harry still holds (tibialis posterior anteriorly and flexor hallucis longus posteriorly). The flexor hallucis longus tendon now runs in a groove behind the sustentaculum tali.* ***(Middle)*** *Coronal scan shows the tarsal tunnel. All structures within the tunnel curve around the medial malleolus to run forward to the midfoot. The tibialis posterior tendon runs on the surface of the deltoid ligament, flexor digitorum longus on the talus, and flexor hallucis longus on the calcaneus under the sustentaculum tali.* ***(Bottom)*** *Transverse image shows the long axis of the tibialis posterior tendon inserting onto the medial pole of the navicular. This insertion is sometimes accompanied by an accessory navicular bone, which may take on different shapes.*

GRAPHICS, MEDIAL AND POSTERIOR LIGAMENTS



(Top) *Medial view shows the ankle. The deltoid ligament is the major supporter of the ankle. It has many variable components, but a commonly accepted division includes the deep anterior and posterior tibiotalar and superficial anterior and posterior tibiotalar, tibiocalcaneal, and tibiospring and tibionavicular bands. Note that the superficial deltoid is band-like and distinction between its various components relies on the sites of insertion.* ***(Bottom)*** *Posterior view shows the ankle. The tibiofibular ligaments are obliquely oriented and their fibular origin is above the fibular fossa. The inferior transverse ligament, which is the inferior aspect of the posterior tibiofibular ligament, extends distal to the tibial posterior surface.*

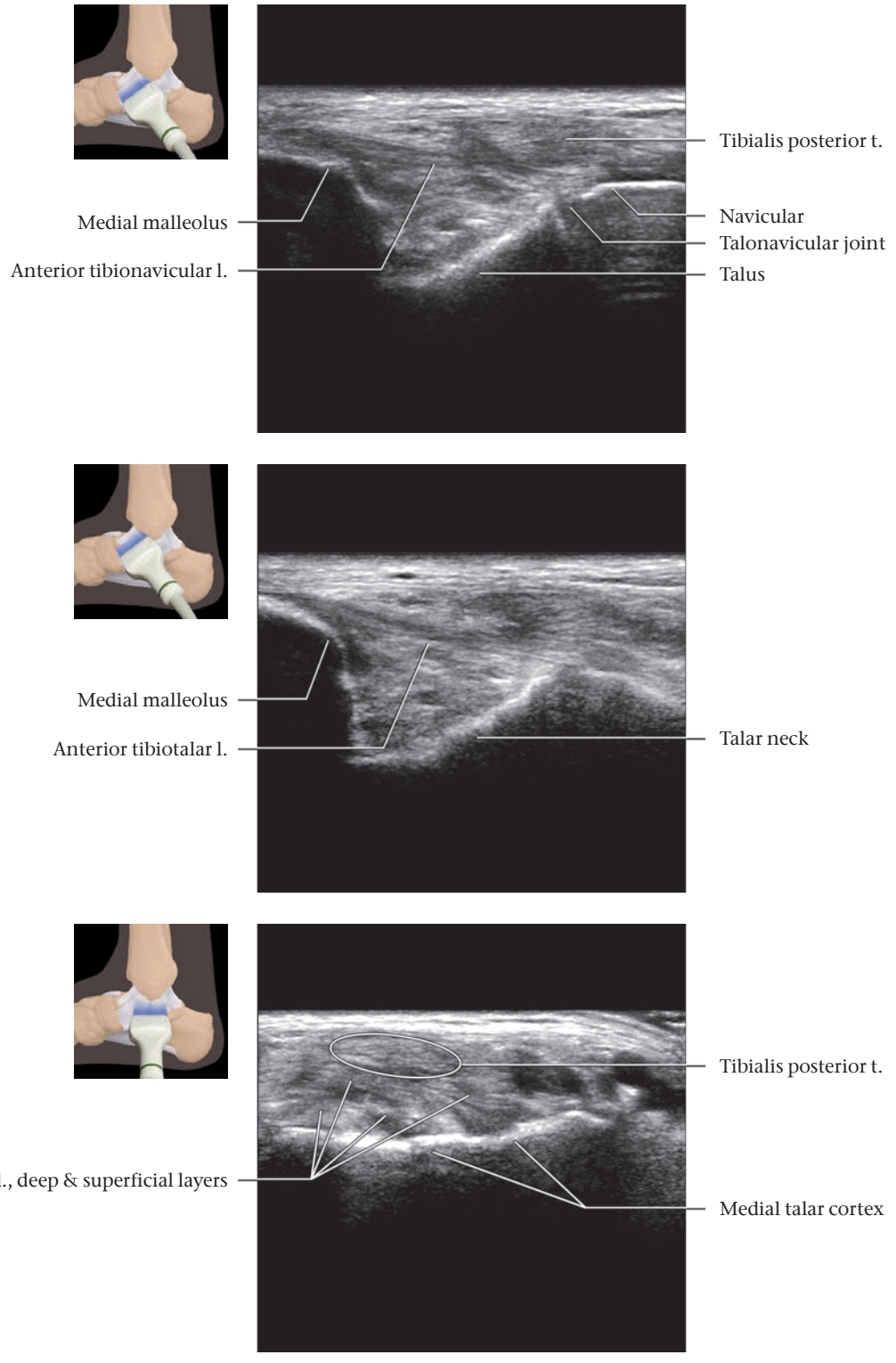
DELTOID LIGAMENT



(Top) *Coronal image is seen through the posterior (posterior tibiotalar) portion of deltoid ligament, which runs from the medial malleolus to the talus. The tibialis posterior and flexor digitorum longus tendons run superficial to this ligament.* ***(Middle)*** *Coronal image through a more anterior portion of the deltoid ligament is shown. The superficial layer (tibiocalcaneal) runs from the malleolus to the sustentaculum tali, the deep component (posterior tibiotalar) to the talus.* ***(Bottom)*** *Coronal image is seen through the midportion of the deltoid ligament. The superficial layer (tibiospring) runs from malleolus to the spring ligament, the deep component to the talus.*

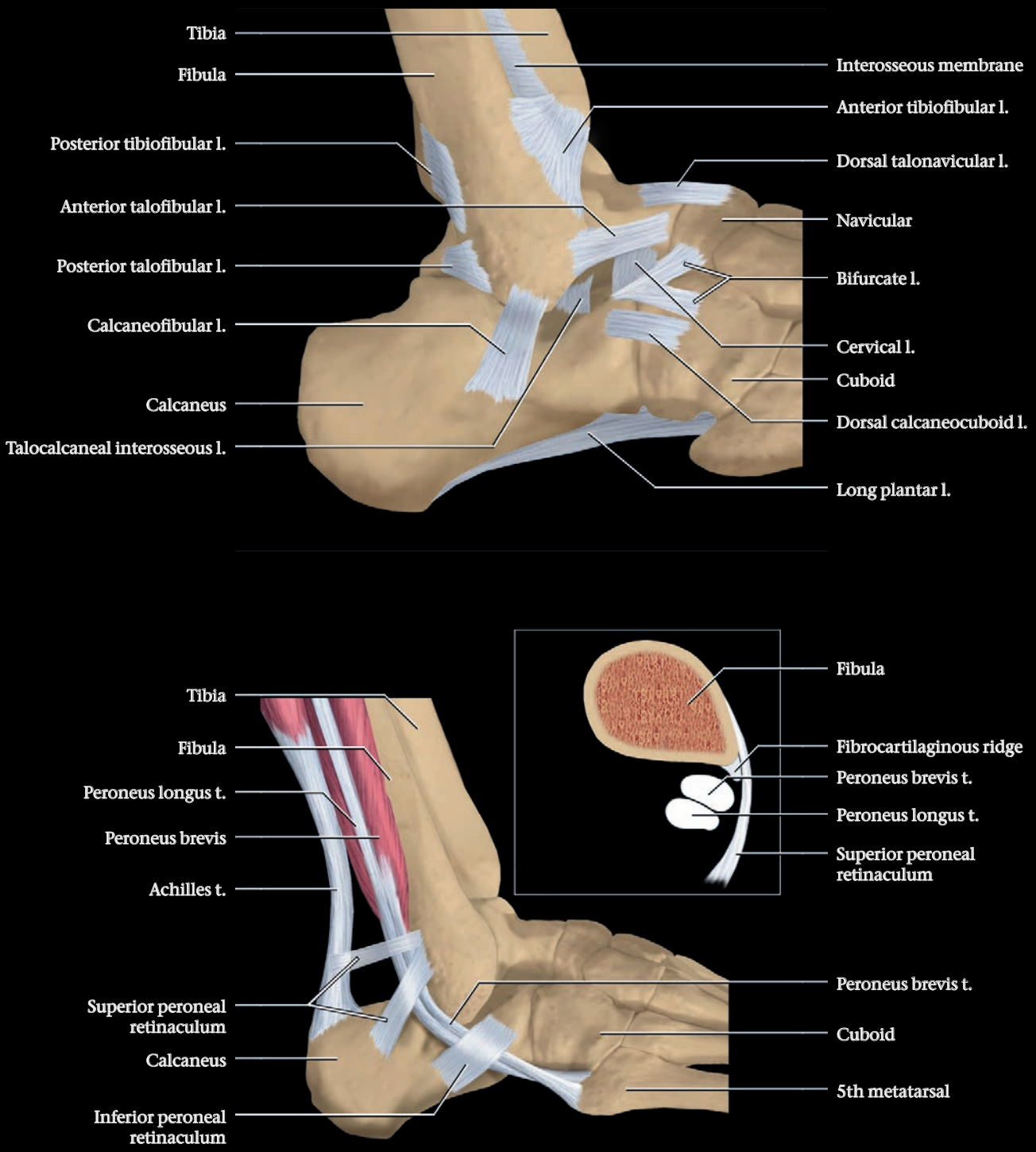
ANKLE

DELTOID LIGAMENT



(Top) *Coronal image is seen through the anterior portion of deltoid ligament; a superficial layer (talonavicular) runs from the malleolus to the navicular.* ***(Middle)*** *Oblique sagittal image is seen through the most anterior portion of the deltoid ligament; fibers (anterior tibiotalar) run from the malleolus to the talar neck. From front to back, these superficial and deep components of the deltoid create a strong restraint against ankle eversion.* ***(Bottom)*** *Transverse scan through medial wall of the talus shows deep and superficial components of the deltoid ligament. The tibialis posterior tendon runs superficial to this ligament.*

LATERAL ANKLE

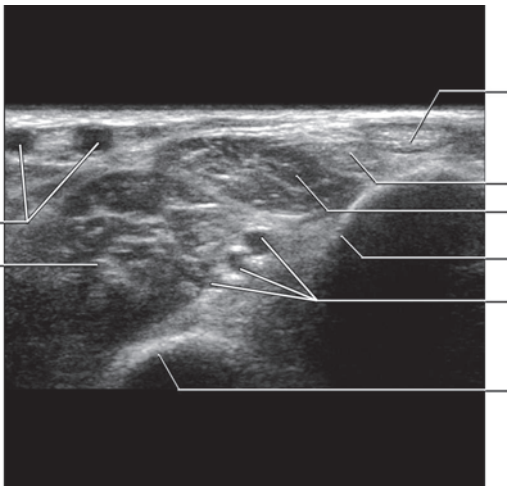


***(Top)** Lateral view shows the ankle. Two groups of lateral ligaments support the ankle: (1) The syndesmotic ligaments, including the anterior tibiofibular, posterior tibiofibular, and syndesmotic ligaments, and (2) the lateral collateral ligaments, including the anterior talofibular, posterior talofibular, and calcaneofibular ligaments. Other ligaments that bind the lateral hindfoot include the talocalcaneal interosseous ligament and cervical ligament in the sinus tarsi. Note the bifurcate ligament, which extends from the calcaneus to the navicular and cuboid. **(Bottom)** Peroneal retinacula is shown. The superior peroneal retinaculum holds the peroneal tendons in the retrofibular groove. The retinaculum has variable insertions but typically inserts on deep fascia of leg and on the calcaneus. The inferior peroneal retinaculum holds the peroneal tendons against the calcaneus.*

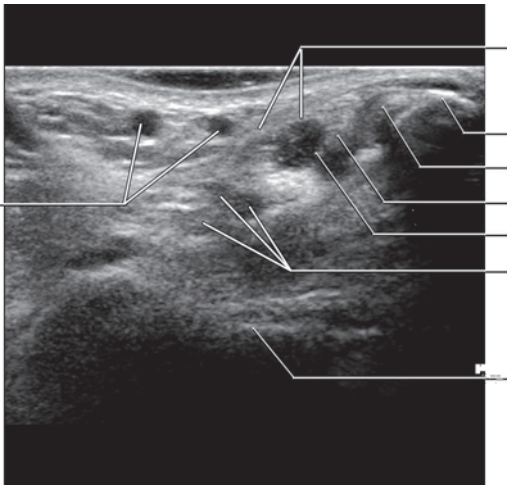
ANKLE

LATERAL ANKLE

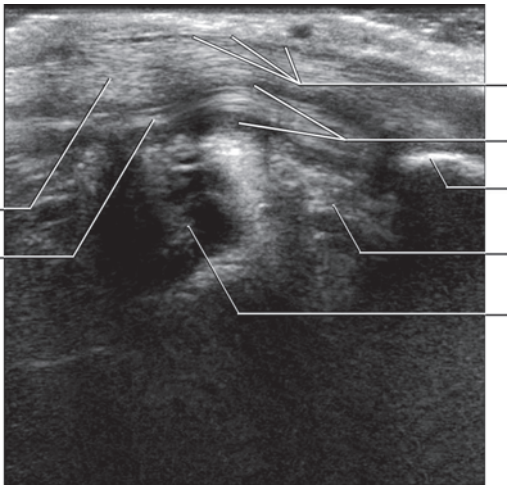




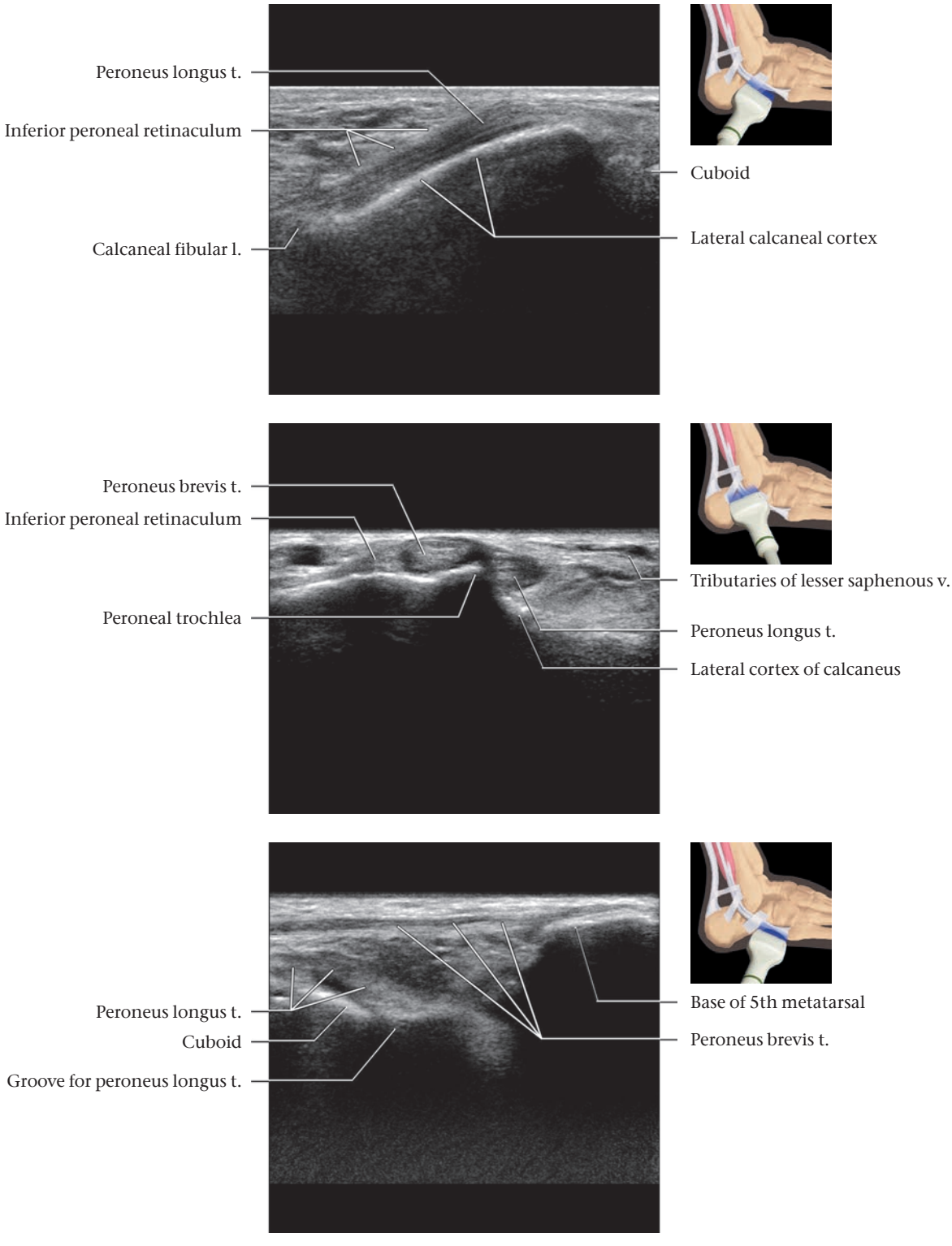








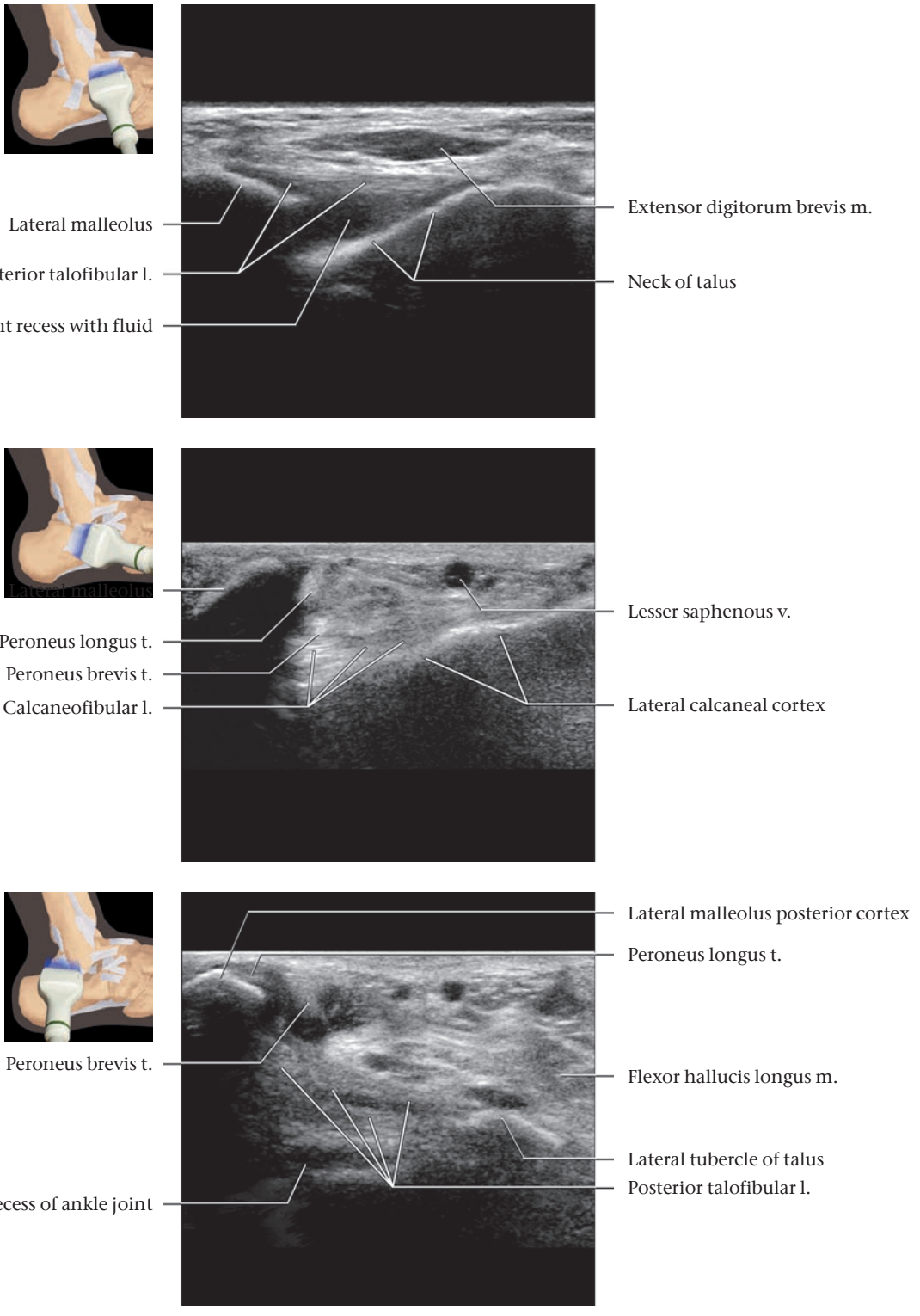
(Top) *Transverse scan of the posterior aspect of the distal fibula shows the distal peroneal muscles. The peroneus longus tendon runs anterior to the peroneus brevis. The latter is easily identified by its muscle component, which continues to just above the tip of the lateral malleolus.* ***(Middle)*** *Transverse scan is shown at the level just above the tip of the lateral malleolus. The peroneal tendons are now held down by the superior peroneal retinaculum, which prevents tendon subluxation (bowstringing). There is still a residual component of the peroneus brevis muscle.* ***(Bottom)*** *Oblique coronal scan of the posterior aspect of the lateral malleolus shows the longitudinal course of the peroneal tendons. Both tendons run inferior onto the lateral surface of the calcaneus, passing over the calcaneal fibular ligament on the way.*



(Top) *Oblique transverse scan shows the lateral aspect of the calcaneus along the course of the peroneus longus tendon. Close to the anterior end of the calcaneus, the peroneus longus turns medially and inferiorly to enter the plantar region.* ***(Middle)*** *Coronal scan of the lateral surface of the calcaneus shows the peroneal tendons held down by the inferior peroneal retinaculum but partially separated by peroneal tubercle, a protuberance on the lateral calcaneal cortex. The peroneus brevis tendon lies more superior than the peroneus longus tendon at this level.* ***(Bottom)*** *Transverse scan of the lateral aspect of the foot shows insertion of the peroneus brevis tendon onto the base of the 5th metatarsal bone. Also shown here is the peroneus longus tendon turning inferiorly on the surface of the cuboid, into a groove solely for this tendon to enter the plantar aspect of the foot.*

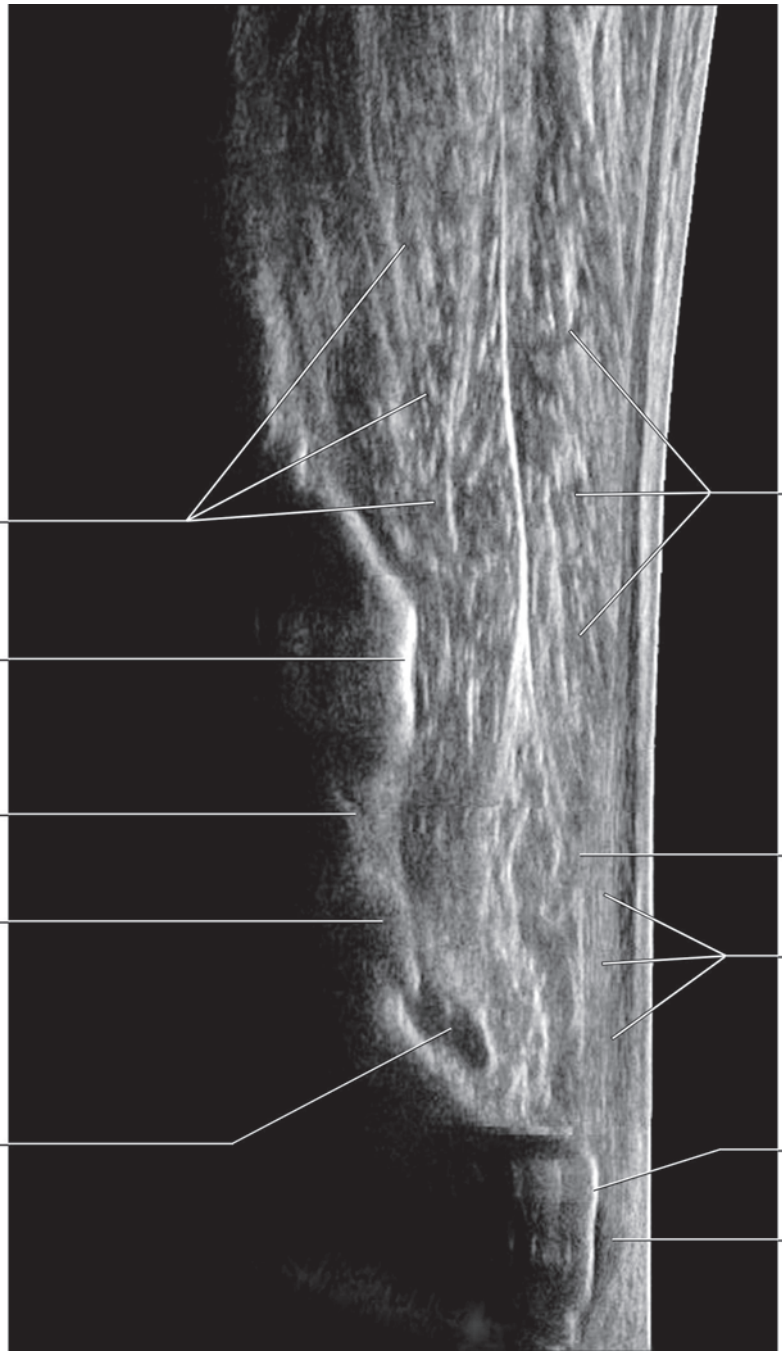
ANKLE

FIBULAR LIGAMENTS



(Top) *Oblique transverse scan shows the lateral ankle along the course of the anterior talofibular ligament. An anterolateral ankle joint recess exists deep to this ligament, making it a good area to look for small effusions. The lateral fibers of the extensor digitorum brevis muscle run on the surface of this ligament.* ***(Middle)*** *Oblique coronal scan along the long axis of the calcaneofibular ligament is shown. The peroneal tendons can be seen curving under the lateral malleolus and running partly on the surface of this ligament.* ***(Bottom)*** *Transverse scan of the posterior aspect of the lateral malleolus shows the posterior talofibular ligament. Deep to this ligament is the posterior recess of the ankle joint.*

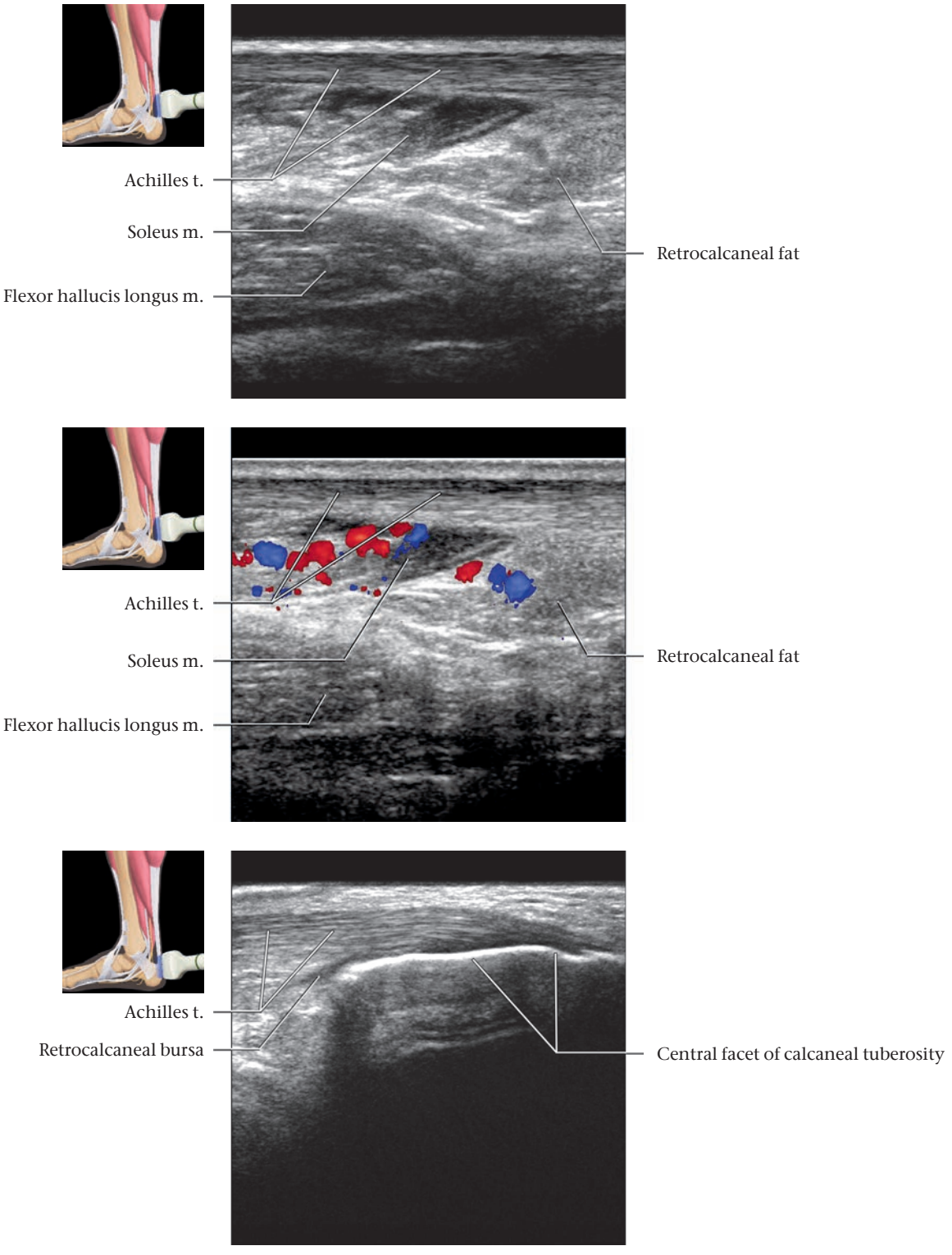
POSTERIOR ANKLE PANORAMA





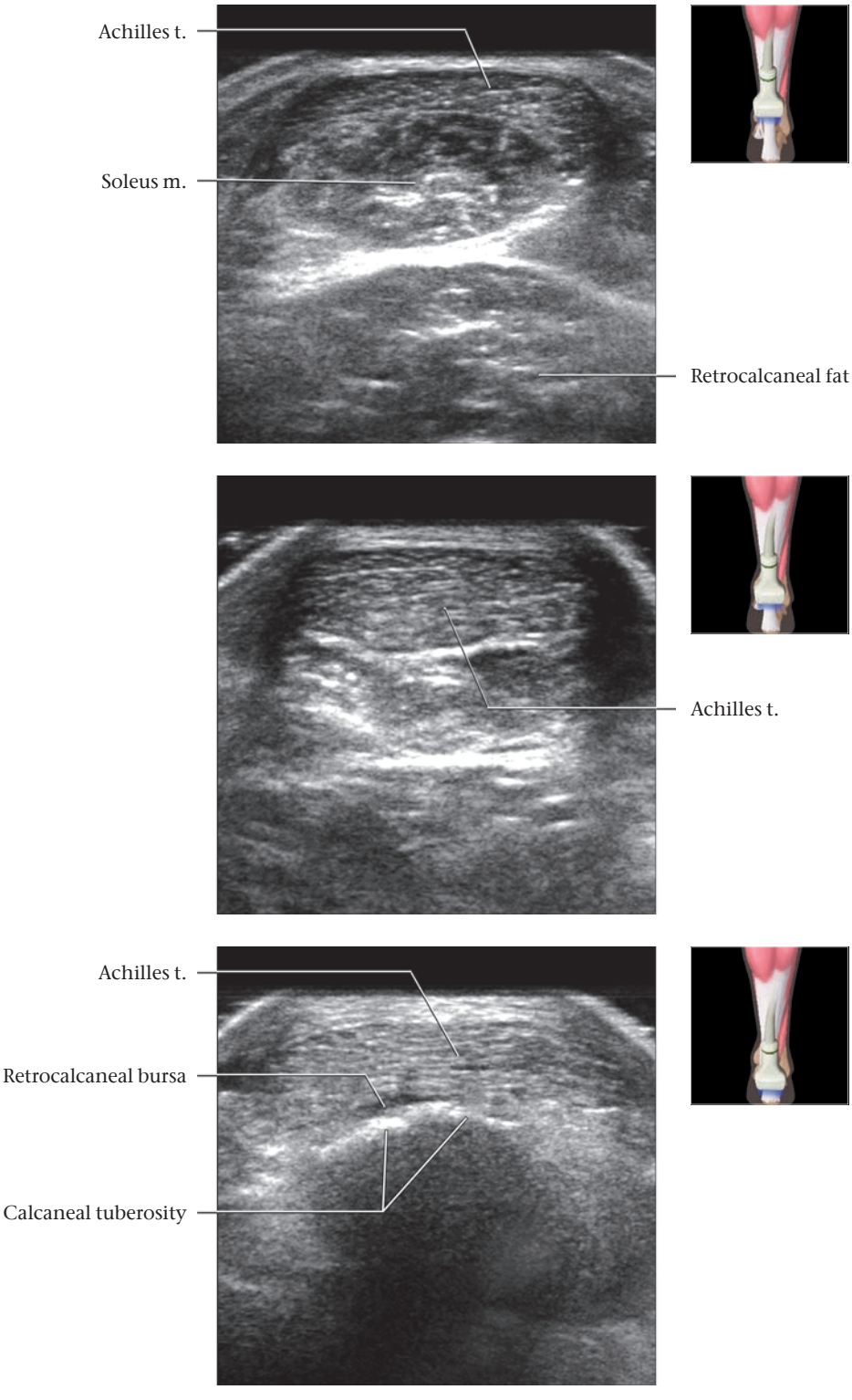
Sagittal panoramic view shows the posterior ankle. The dominant structure in the posterior ankle is the Achilles tendon, the largest tendon in the body. This runs craniocaudally just under the skin and is well demonstrated by ultrasound. The ankle should be in dorsiflexion to tighten this tendon during examination so that the organization of its fibers and continuity can be assessed. More superiorly, its contributing muscles, the soleus and gastrocnemius, can be traced. Deep to the Achilles tendon is the flexor hallucis longus muscle. An accessory soleus muscle may be seen inferomedial to the Achilles tendon. It occurs in 30% of the normal population and may be symptomatic in athletes with low-grade pain and stiffness after exercise.

ACHILLES TENDON, LONGITUDINAL



(Top) *Sagittal scan of the lower posterior leg shows the musculotendinous junction between the soleus muscle and the Achilles tendon. These structures join at an angle with a crisp border. A disruption of this sharp transition (usually due to hemorrhage and rupture of inserting muscle fibers) is suggestive of injury to the musculotendinous junction.* ***(Middle)*** *Color Doppler scan of the same region shows the rich blood supply to this region and the cause for extensive bruising in tendon damage at this site.* ***(Bottom)*** *Sagittal scan more distally shows the insertion of Achilles tendon onto the middle facet of the posterior calcaneal surface. The retrocalcaneal bursa separates the Achilles tendon from the superior facet of the posterior calcaneal surface. This bursa usually contains a tiny amount of fluid detectable on ultrasound.*

ACHILLES TENDON, AXIAL



(Top) *Series of transverse scans through the Achilles tendon is shown. At a superior level, the soleus muscle can be seen deep to the Achilles tendon. The Achilles tendon begins superiorly as a continuation of the gastrocnemius aponeurosis, which then joins with the soleus tendon to form the Achilles tendon. At the level of this scan, the tendon is crescent shaped to accommodate the soleus muscle.* ***(Middle)*** *Transverse scan shows the Achilles tendon at its midportion. The tendon now assumes an oval shape. The fibrils within the tendon produce a coarsely dotted appearance. Focal hypoechogenicity or change in shape of this tendon should suggest tear/rupture or tendinosis.* ***(Bottom)*** *At a lower level before its insertion onto the calcaneal tuberosity, the Achilles tendon becomes flattened. A small amount of fluid is frequently seen in the retrocalcaneal bursa deep to the tendon.*

TARSUS

TERMINOLOGY

Abbreviations
- Artery (a.)
- Ligament (l.)
- Muscle (m.)
- Nerve (n.)
- Vein (v.)

Definitions
- **3 major divisions**
  - **Hindfoot**: Calcaneus and talus
  - **Midfoot**: Navicular, cuneiforms, and cuboid
  - **Forefoot**: Metatarsals and phalanges
- **2 columns**
  - **Medial column**: Talus, navicular, cuneiforms 1-3, digits 1-3
  - **Lateral column**: Calcaneus, cuboid, digits 4 and 5
- Some authors use 2 columns in hind and midfoot as above, but divide forefoot into 3 columns
  - Medial column: 1st toe
  - Middle column: 2nd-4th toes
  - Lateral column: 5th toe

IMAGING ANATOMY

Overview
- Alignment of foot can only be assessed on weight-bearing radiographs

Arches of Foot
- Foot is arched from posterior to anterior and from medial to lateral
- **Transverse arch of foot**
  - Cuneiform bones form keystone of arch due to triangular shape
  - Major supporting structures of transverse arch
    - Spring ligament
    - Lisfranc ligament and intermetatarsal ligaments
    - Intertarsal ligaments
- **Longitudinal arch of foot**
  - From posterior process calcaneus to metatarsal heads
  - Medial side is higher than lateral
  - Apex of arch is at navicular and cuneiforms
  - Metatarsals slant downward from apex of arch to metatarsophalangeal (MTP) joint
    - This is called inclination angle
    - Inclination angle decreases from 20˚ at 1st to 5˚ at 5th metatarsal
  - Major supporting structures of longitudinal arch
    - Plantar fascia
    - Long and short plantar ligaments
    - Spring ligament
    - Posterior tibial tendon, peroneus longus tendon
- **Radiographic assessment of normal longitudinal arch**
  - Evaluate talometatarsal alignment
    - Normal: Axis of talus continues along axis of 1st metatarsal
    - Pes planus: Axis of talus points below axis of 1st metacarpal, due to flattened arch
    - Pes cavus: Axis of talus points above axis of 1st metacarpal, due to exaggerated arch

Distribution of Weight Bearing
- 50% of weight is borne on subtalar joint and calcaneus
- Remainder is transmitted via arch anteriorly to metatarsophalangeal joints, greatest weight on 1st toe

Bony Anatomy
- **Cuboid bone**
  - Roughly cuboidal shape
  - 1 ossification center: Ossifies between 9th fetal month and 6 months of age
  - Articulates with calcaneus, navicular, 3rd cuneiform, and 4th and 5th metatarsals, rarely head of talus
    - Dorsal ligaments (calcaneocuboid, cubonavicular, cuneocuboid, cubometatarsal) strengthen each of these articulations
    - Short and long plantar ligaments attach to plantar surface
  - Sulcus at lateral margin, under which passes peroneus longus tendon
  - 5th metatarsal base extends beyond lateral margin
- **Navicular bone**
  - Curved shape, concave proximally and convex distally
  - 1 ossification center: Ossifies in 3rd year of life
  - Articulates with talus, cuboid, cuneiforms
    - Dorsal ligaments strengthen each of these articulations
    - Single facet proximally for articulation with head of talus
    - 3 facets distally for cuneiform articulations
    - 1 facet laterally for articulation with cuboid
    - Connected to anterior process of calcaneus by bifurcate ligament
    - Connected to sustentaculum tali by spring ligament
  - Large median eminence for attachment of posterior tibial tendon is located more plantar than main body of navicular
- **Cuneiform bones**
  - Wedge-shaped, with base of wedge at dorsal surface of 2nd and 3rd cuneiforms, dorsomedial surface 1st cuneiform
  - In combination, form arch
  - 1st cuneiform (medial cuneiform)
    - Articulates with navicular, 2nd cuneiform, 1st metatarsal
    - 1 or 2 ossifications centers: Ossify in 2nd year of life
  - 2nd cuneiform (middle or intermediate cuneiform)
    - Articulates with navicular, 1st and 3rd cuneiforms, 2nd metatarsal
    - Smallest of cuneiforms
    - 1 ossification center: Ossifies in 3rd year of life
  - 3rd cuneiform (lateral cuneiform)
    - Articulates with navicular, 2nd cuneiform, cuboid, 3rd metatarsal
- **Metatarsal bones**
  - 2 ossifications centers: Shaft ossifies in 9th prenatal week, epiphysis in 3rd-4th years of life
    - 1st metatarsal has epiphysis at proximal end, others at distal end
  - 2nd-5th metatarsals have articulations at bases with adjacent metatarsals
  - 1st metatarsal
    - Largest of metatarsals
    - Articulates with 1st cuneiform, 1st proximal phalanx, sesamoids of metatarsal head
    - Variable articulation with 2nd metatarsal base

- 2nd-3rd metatarsals
  - Articulate with respective cuneiforms and proximal phalanges
  - 2nd metatarsal base recessed relative to 1st and usually 3rd
- 4th-5th metatarsals
  - Articulate with cuboid and respective proximal phalanges
  - Styloid process of 5th metatarsal extends lateral to cuboid

· **Phalanges**
- 1st toe is biphalangeal, other toes are triphalangeal
- 5th toe sometimes has failure of segmentation of middle and distal phalanges
- 2 ossification centers: Shaft ossifies 9th-15th prenatal weeks, epiphysis 2nd-8th years

Musculature

· **Plantar muscles**: 4 muscle layers, numbered from superficial to deep
- 1st layer: Abductor hallucis, flexor digitorum brevis, abductor digiti minimi
- 2nd layer: Quadratus plantae (flexor accessorius), flexor digitorum and hallucis longus tendons, lumbricals
- 3rd layer: Flexor hallucis brevis, adductor hallucis, flexor digiti minimi brevis, tibialis posterior tendon
- 4th layer: Plantar interossei (3), dorsal interossei (4)
- Peroneus longus tendon courses across all layers, from superficial plantar laterally to deep plantar medially

· **Dorsal muscles**: 2 muscle layers
- Superficial layer: Tibialis anterior tendon, extensor hallucis longus tendon, extensor digitorum longus tendon, peroneus tertius tendon
- Deep layer: Extensor hallucis brevis, extensor digitorum brevis
- In forefoot, long and short extensors run side by side in single layer

Compartments

· **Plantar compartments: 4 plantar compartments are located** deep to plantar fascia
- Divided by fascial layers
- Lateral and medial intermuscular septa determine major compartment divisions
- **Medial plantar compartment**
  - Contains abductor hallucis, flexor hallucis longus, and flexor hallucis brevis tendons
- **Central plantar compartment**
  - Superficial subcompartment: Contains flexor digitorum brevis, distal portion of flexor digitorum longus tendons
  - Intermediary subcompartment: Contains proximal plantar portion of flexor digitorum longus tendon, quadratus plantae, lumbricals
  - Deep subcompartment: Limited to forefoot, contains adductor hallucis
- **Lateral plantar compartment**
  - Contains abductor and flexor digiti minimi
- **Interosseous compartment**
  - Contains plantar and dorsal interosseous muscles

· **Dorsal compartment**
- Superficial layer: Extrinsic extensor tendons
- Deep layer: Intrinsic extensor muscles

Major Ligaments

· Plantar fascia (aponeurosis): 3 portions extend from tuberosity of calcaneus to transverse metatarsal ligaments of toes
- Medial band: Thin structure superficial to abductor hallucis muscle
- Central band: Thick, strong structure superficial to flexor digitorum brevis
  - Divides into separate bands to each toe; these are linked by transverse bands
  - Distally sends septa superficially into subcutaneous fat and deep to MTP joints
- Lateral band: Thin structure superficial to abductor digiti minimi
- Medial and lateral bands sometimes terminate at level of midmetatarsals

· Long plantar ligament: Originates at calcaneal tuberosity, inserts at cuboid and bases of 2nd-4th metatarsals
- Forms retinaculum for peroneus longus tendon as it courses medially on plantar aspect of foot

· Short plantar (plantar calcaneocuboid) ligament: Deep to long ligament, inserts more proximally on cuboid

· Plantar calcaneocuboid (spring) ligament: Originates on sustentaculum tali, inserts on plantar aspect navicular

· Bifurcate ligament: Originates on anterior process of calcaneus dorsally, inserts on navicular and cuboid

· Lisfranc ligament: Originates at 1st cuneiform, inserts at base of 2nd metatarsal

· Intermetatarsal ligaments: Dorsal and plantar ligaments between 2nd-5th metatarsal bases

· Transverse metatarsal ligaments: Superficial and deep ligaments between metatarsal heads

Nerves

· **Tibial nerve** divides into medial and lateral plantar branches at level of tarsal tunnel
- **Medial plantar nerve**
  - Between 1st and 2nd muscle layers, accompanies medial plantar artery
  - Motor branches: Abductor hallucis, flexor digitorum and hallucis brevis, 1st lumbrical
  - Plantar digital nerves to 1st-3rd toes, medial aspect of 4th toe
- **Lateral plantar nerve**: Has deep and superficial divisions
  - Motor branches: Flexor digiti minimi brevis, lumbricals, interossei, adductor hallucis
  - Superficial lateral plantar nerve: Between 1st and 2nd muscle layers
  - Plantar digital nerves to 5th toe, lateral aspect of 4th toe
  - Deep lateral plantar nerve: Between 3rd and 4th muscle layers; accompanies lateral plantar artery

· **Deep peroneal nerve**: Extends along dorsum of foot, between tibialis anterior and extensor hallucis longus
- Motor branch: Extensor digitorum brevis

· **Superficial peroneal nerve**: Divides into medial and lateral branches at dorsum of foot
- Sensory branches to dorsal foot

· **Sural nerve**: Lateral, superficial branch of tibial nerve
- Extends along lateral margin of foot
- Sensory branches to lateral foot

TARSUS

Arteries

- Posterior tibial artery divides into medial and lateral plantar arteries at level of tarsal tunnel
  - Plantar arteries accompany medial and deep lateral plantar nerves
- Peroneal artery accompanies superficial peroneal nerve down anterolateral aspect of ankle
  - May join or replace posterior tibial artery
- Anterior tibial artery continues into foot as dorsalis pedis artery, deep to extensor retinaculum
  - Divides into multiple branches in midfoot, forming arcade

Bursae

- Extensor digitorum brevis: Between muscle and 2nd cuneiform and metatarsal bases
- Extensor hallucis longus: Between tendon and 1st cuneiform and metatarsal bases
- Abductor digiti minimi: Between muscle and tuberosity of 5th metatarsal
- Metatarsophalangeal joints: Dorsally between metatarsal heads and medial to 1st metatarsal head

ANATOMY IMAGING ISSUES

Imaging Recommendations

- Radiographs
  - Weight bearing, when possible
  - Standard views: Anteroposterior (dorsoplantar), lateral, oblique
- US
  - Offers highest spatial resolution for muscle and tendons
  - Particularly useful given limited depth of most soft tissue structures in foot
  - As a result of transverse arch of foot, interrogation should be performed separately for medial and lateral sides for best visualization
  - Due to complex soft tissue anatomy, panoramic (extended field of view) images provide better depiction of location and extent of a lesion and course of different structures
  - Dorsal foot structures tend to be very superficial and thin (tendons) or compressible (vessels)
    - To better visualize these structures, minimal compression and a thick layer of coupling gel may help
- CT
  - Multidetector 1 mm images with sagittal and coronal reformations
  - 3-dimensional reconstructions often useful for analyzing relationship between bones and bone fragments
- MR
  - Better images obtained when field of view is limited to area of concern, not entire foot
  - Demonstration of bone marrow edema aside from soft tissue lesions

Imaging Sweet Spots

- Tendon movement can be easily demonstrated with ultrasound by moving bone onto which it inserts
  - Helps with confirming tendon location and also with establishing tendon integrity
- Tarsal ligaments are usually seen as hypoechoic thickenings on cortices and between bones
  - Orientation of transducer along long axis makes ligament stand out and easier to identify

Imaging Pitfalls

- Alignment can only be reliably assessed on weight-bearing radiographs

CLINICAL IMPLICATIONS

Foot Motion

- **Supination**: Elevation of medial arch of foot
  - Combination of inversion and adduction
- **Pronation**: Depression of medial arch of foot
  - Combination of eversion and abduction
- Complex motions at multiple joints
  - Chopart (calcaneocuboid and talonavicular) joint
    - These 2 joints move together on an oblique axis to produce compound motions
    - Pronation-abduction-extension to supination-adduction-flexion
  - Tarsometatarsal joints
    - Dorsiflexion and plantar flexion
    - 2nd and 3rd tarsometatarsal joints relatively immobile
    - Slight abduction of 1st tarsometatarsal joint
  - Metatarsophalangeal joints
    - Dorsiflexion and plantar flexion
    - Abduction and adduction at 1st metatarsophalangeal joint

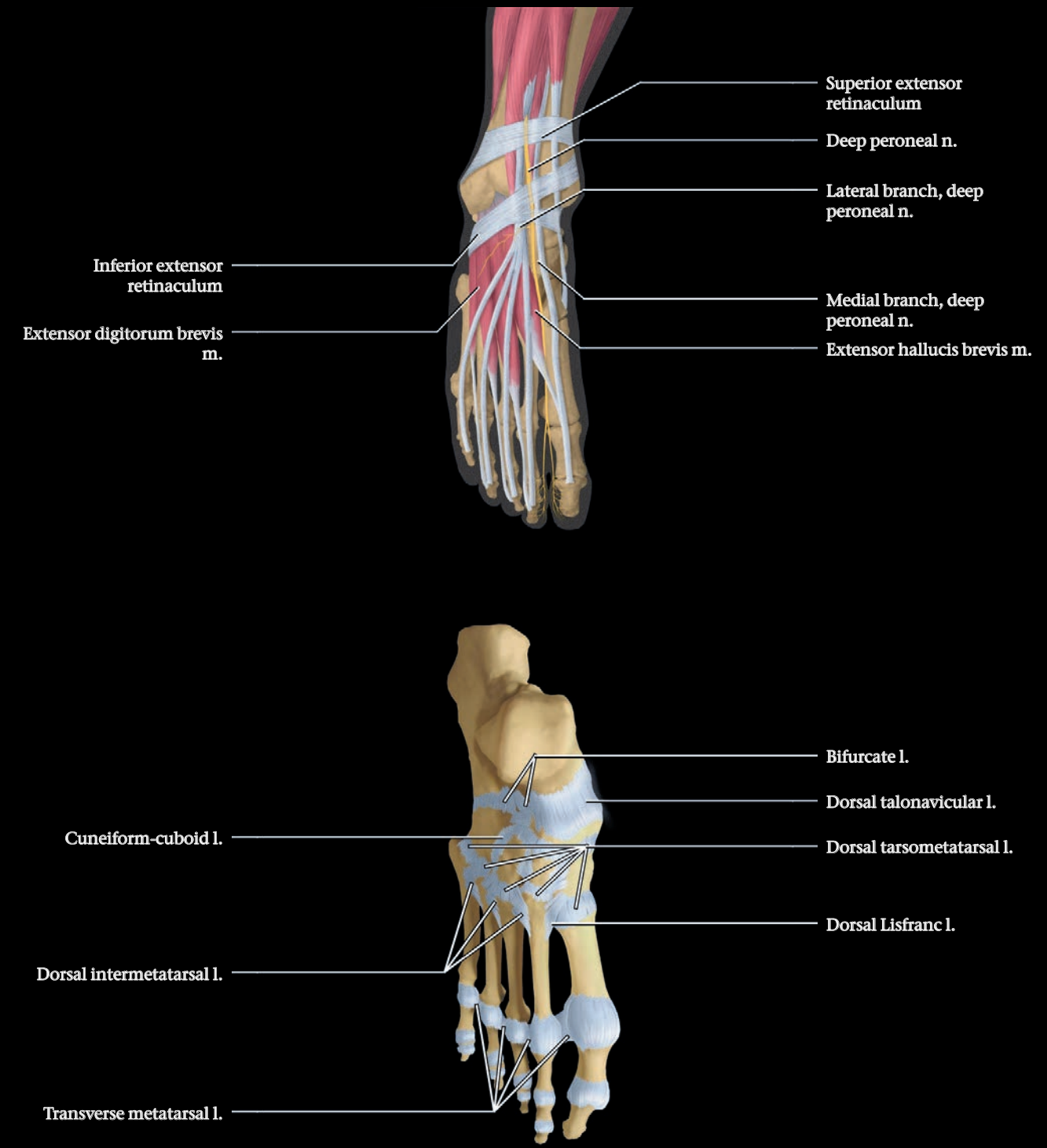
Alignment

- Normal weight bearing and gait depend on normal foot alignment
- Evaluated initially with anteroposterior and lateral weight-bearing radiographs

Malalignment

- Forefoot adductus: Medial angulation of metatarsals from axis of hindfoot
- Forefoot varus: Inversion of metatarsals resulting in shift of weight bearing to 5th metatarsal from 1st metatarsal
- Metatarsus primus varus: Medial deviation of 1st metatarsal axis relative to 2nd
- Hallux valgus (hallux abductus): Lateral deviation of 1st proximal phalanx relative to axis of 1st metatarsal
  - Valgus refers to an angular deformity in vertical plane, where apex points medially
  - Abductus refers to an angular deformity in horizontal plane, where apex points medially
  - Hallux valgus is a misnomer, but it remains the term commonly used for hallux abductus

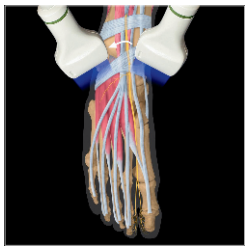
GRAPHICS, DORSAL FOOT

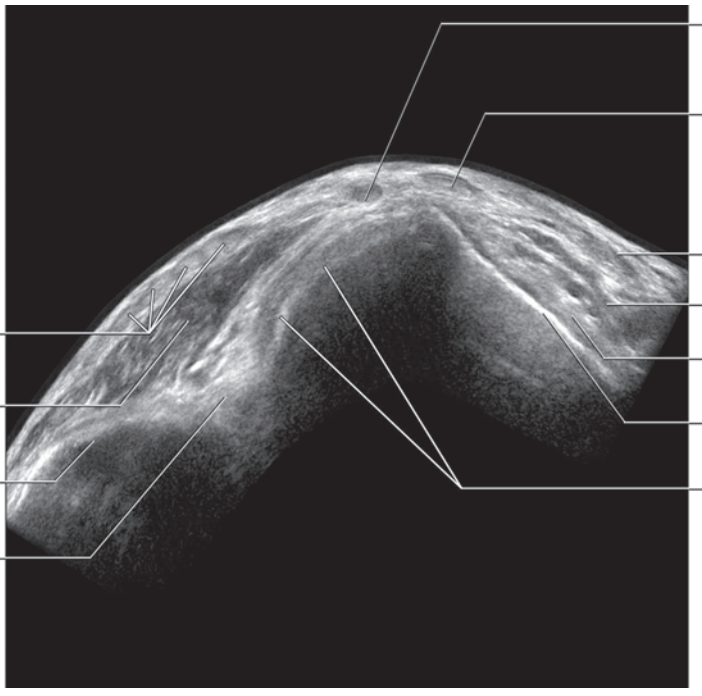


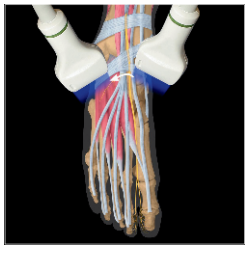
(Top) *The deep peroneal nerve travels deep to the extensor retinacula, in the anterior tarsal tunnel, and gives a lateral motor branch to the extensor digitorum brevis muscle. The medial branch continues dorsal to the talonavicular joint, middle cuneiform and in between the 1st and 2nd metatarsals to provide mostly sensory but some motor supply to the 1st web space.* ***(Bottom)*** *Graphic of the dorsal ligaments shows dense ligaments between the tarsal bones and between tarsals and metatarsals. Ligaments are generally named for the bones they bridge. Exceptions are the bifurcate ligament, which extends from the anterior process of the calcaneus to the cuboid and the navicular, and the dorsal Lisfranc ligament, from the 1st cuneiform to the 2nd metatarsal.*

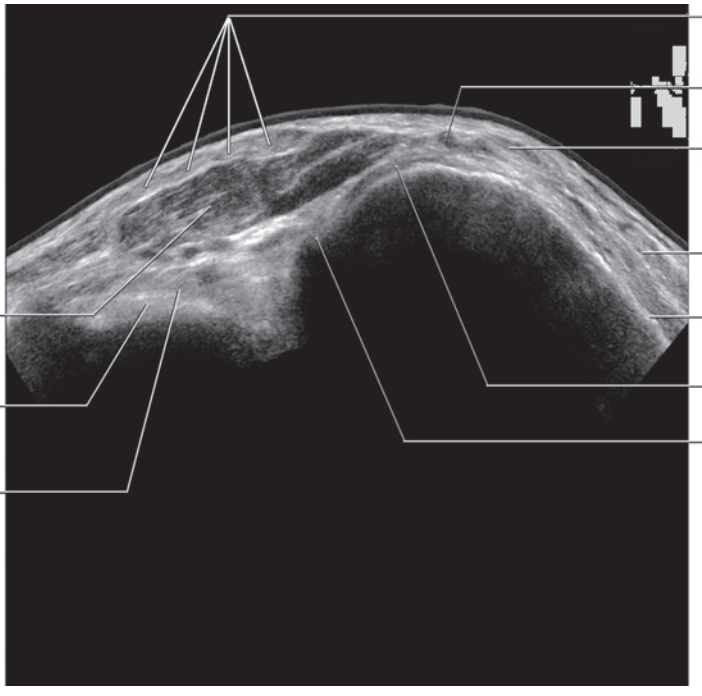
TARSUS

DORSAL FOOT

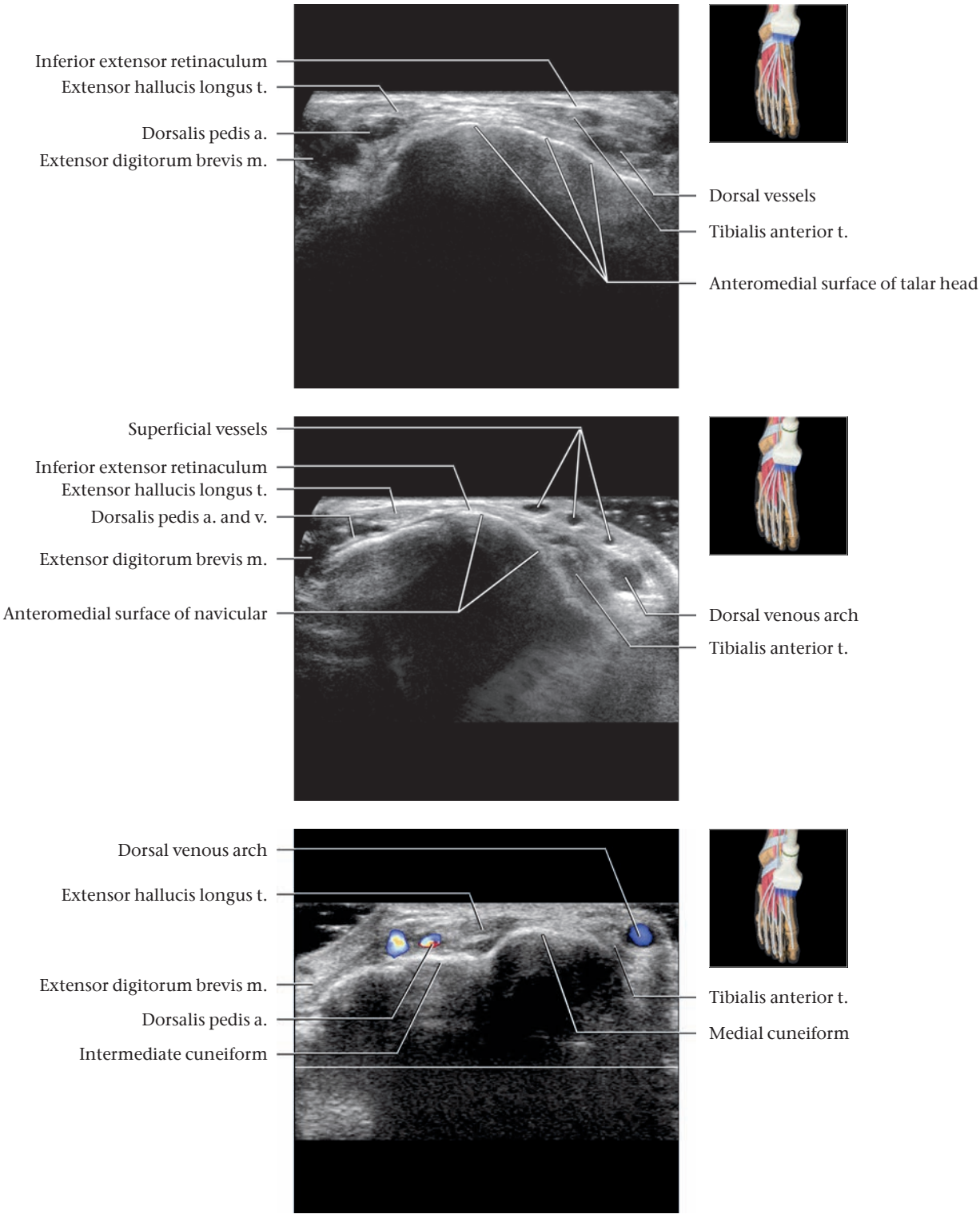








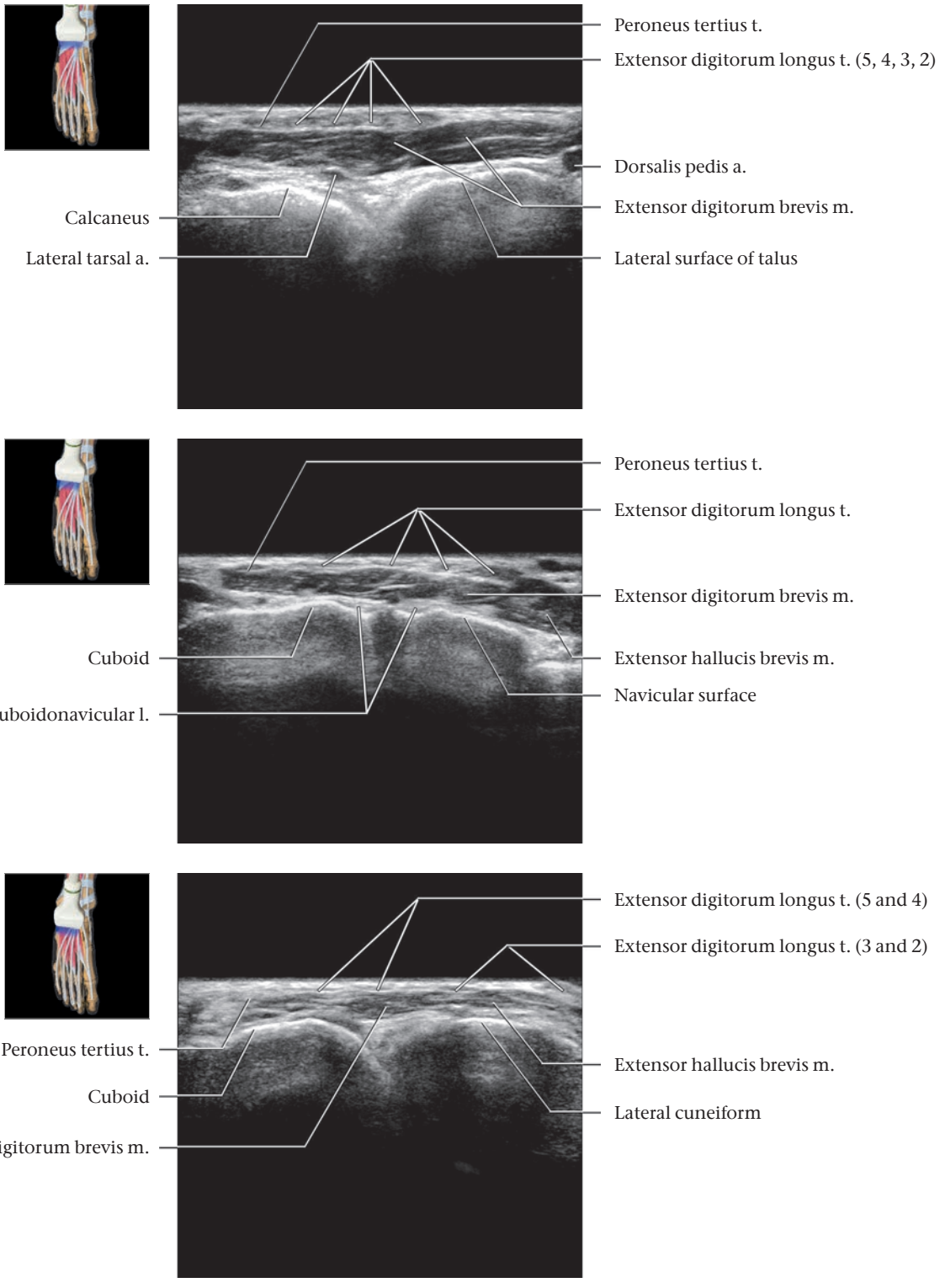
(Top) *Coronal panoramic scan shows the dorsal foot at the talocalcaneus level. The foot can be divided into 2 columns: The medial column (talus, navicular, and cuneiforms) and lateral column (calcaneus and cuboid) form the anteromedial and anterolateral surfaces of the transverse midfoot arch. The dorsalis pedis artery runs at the apex of this arch.* ***(Bottom)*** *Coronal panoramic scan shows the dorsal foot through the navicular-calcaneal level. The transverse arch of the dorsal foot creates 2 surfaces: Anteromedial and anterolateral, over which extensor tendons and small muscles lie. More focal examination of these structures requires scanning along each surface separately. Panoramic scans give an overview of anatomy. However, high-resolution imaging of the site of interest provides more details, and both should be performed as complementary techniques.*



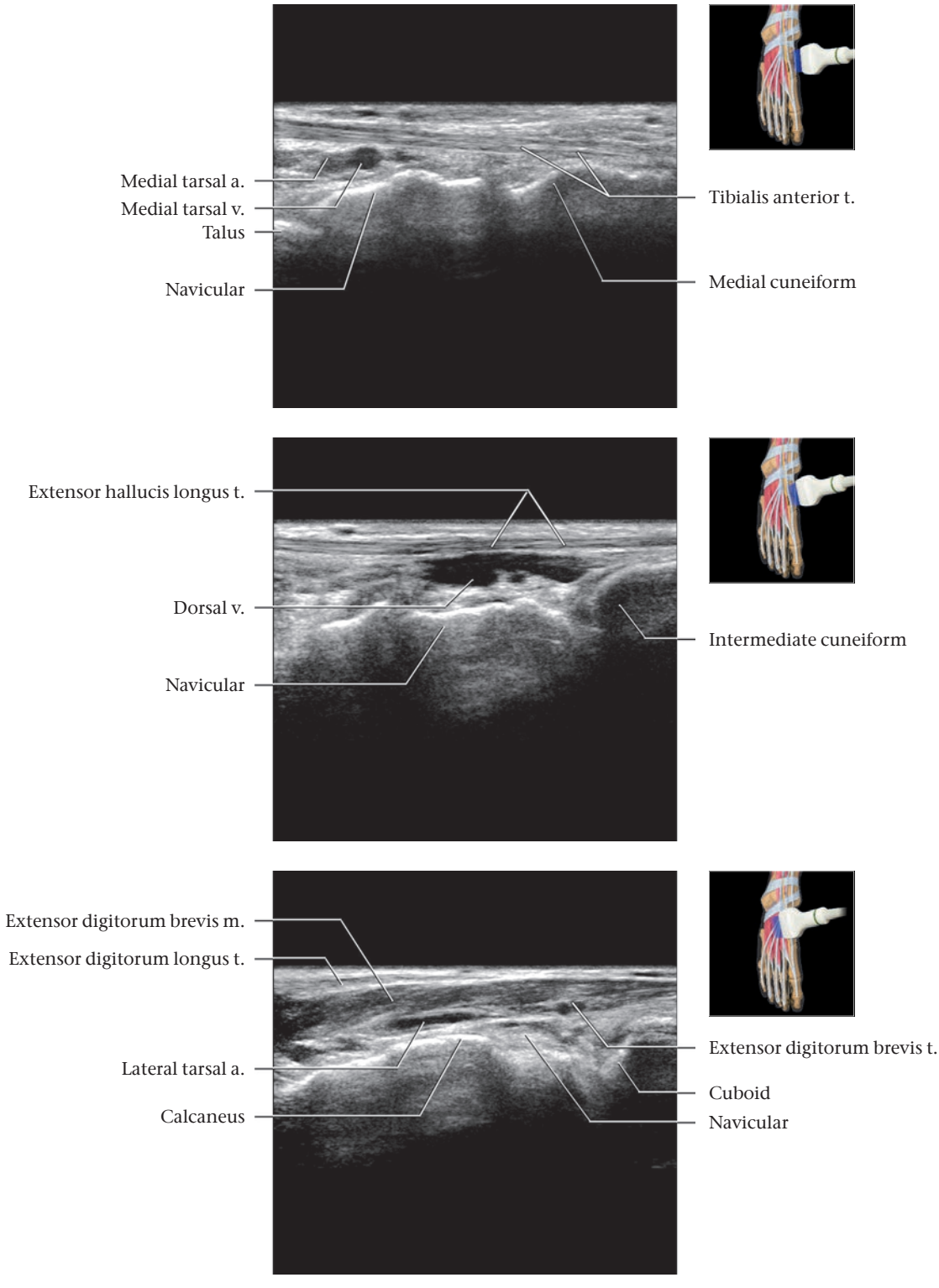
(Top) *Series of 3 coronal scans shows the dorsal medial surface of the foot. At this most proximal level, the talus is the underlying bone. The extensor hallucis can be seen partially covering the dorsalis pedis artery. More medially, the tibialis anterior tendon can be found.* ***(Middle)*** *At a midtarsal level, this coronal scan shows the anteromedial surface of the navicular. The tibialis anterior tendon begins to turn acutely medially to curve around to the medial edge of the foot, eventually inserting on the medial cuneiform. As seen here, the use of light pressure and copious amounts of gel will allow visualization of small superficial veins, which are numerous on the dorsum of the foot.* ***(Bottom)*** *Coronal color Doppler scan shows the level of the cuneiforms. The intimate relationship between the dorsalis pedis artery and the extensor hallucis longus tendon continues.*

TARSUS

DORSAL FOOT

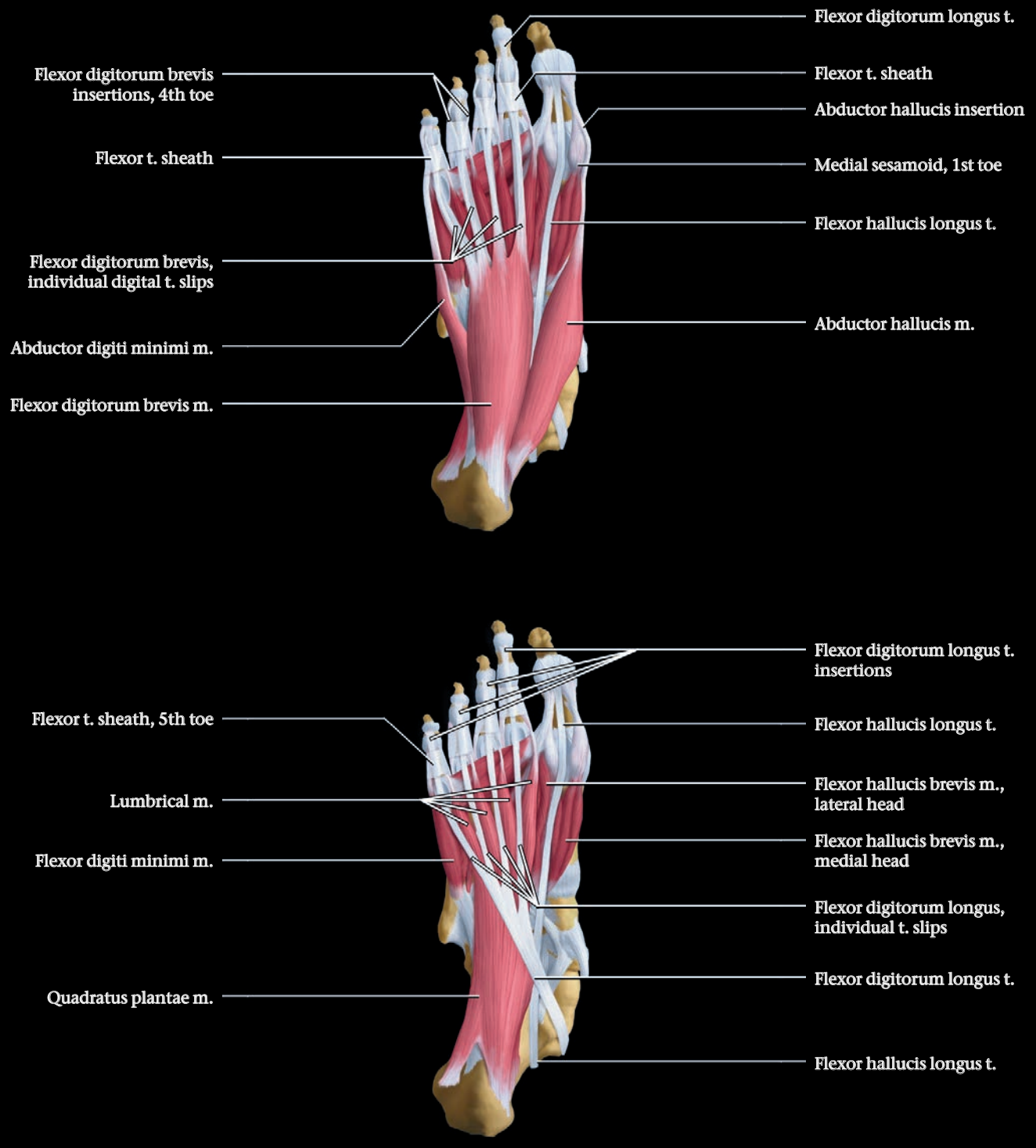


(Top) *Series of 3 coronal scans are seen over the dorsal lateral surface of the tarsus. At this proximal level, the lateral surface of the calcaneus and the talus are the underlying bones. The extensor digitorum longus tendons are close to each other and share a common synovial sheath. The extensor digitorum brevis muscle lies deep to the longus tendons. The lateral tarsal artery runs deeper and is a branch of the dorsalis pedis artery.* ***(Middle)*** *At the level of the midtarsus, the extensor digitorum longus tendons for individual toes begin to spread out and also flatten (the latter making them just discernible on ultrasound). At this level, the extensor hallucis brevis muscle can also be seen.* ***(Bottom)*** *At a more distal level, the extensor digitorum brevis muscle and the extensor hallucis brevis muscle are much thinner and will turn into tendons distally.*



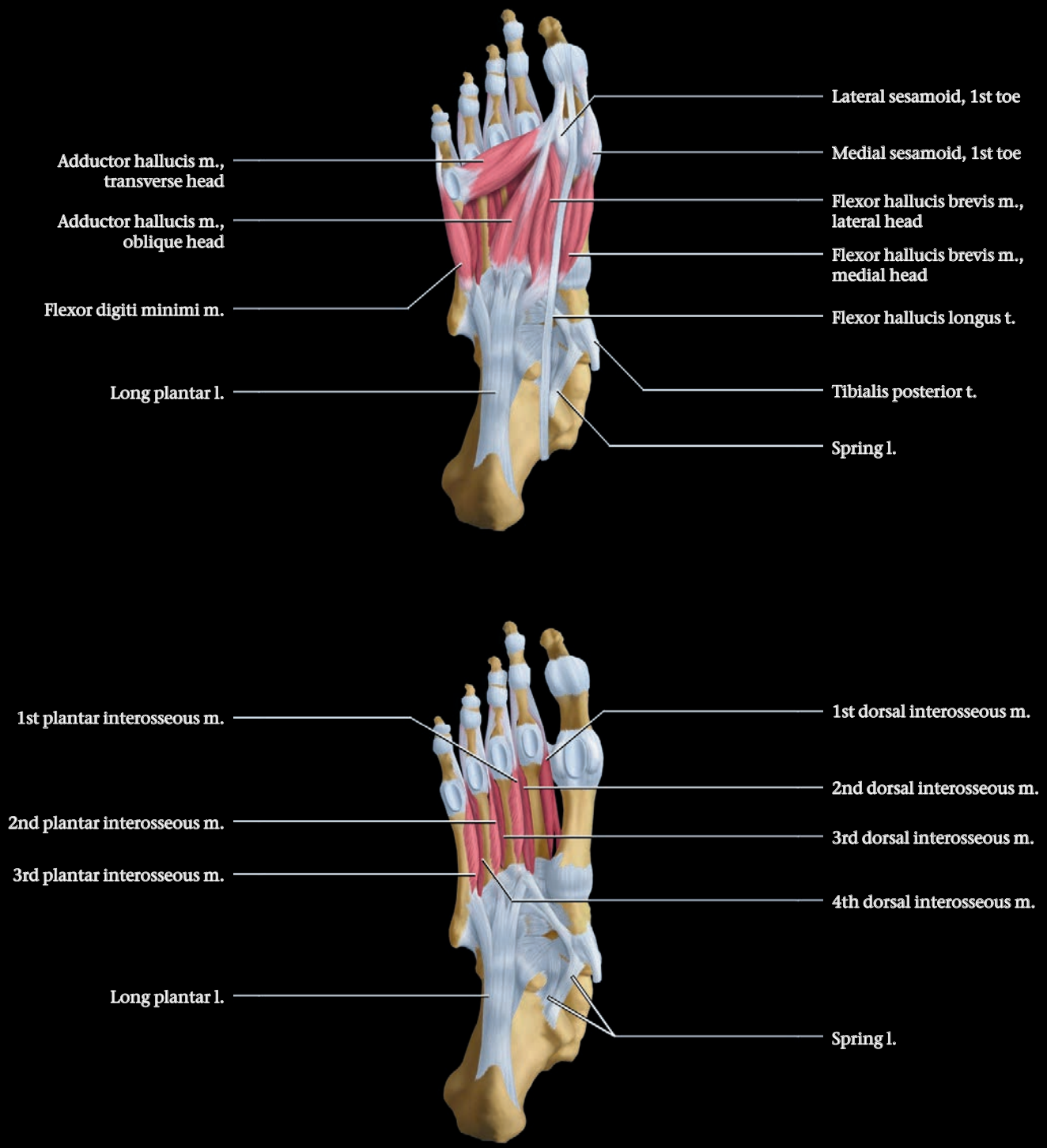
(Top) *Series of sagittal scans are shown through the tarsus. Medially, the tibialis anterior is seen running over the medial tarsal vessels (branch of dorsalis pedis) to insert on the medial and inferior surfaces of the base of the medial cuneiform.* ***(Middle)*** *Slightly laterally, the extensor hallucis longus tendon runs toward the big toe, passing over the intermediate cuneiform bone.* ***(Bottom)*** *More laterally, the extensor digitorum longus tendon and the extensor digitorum brevis muscle come into view. They lie on the surface of the calcaneus with the lateral tarsal artery coursing between the muscle and bone. The gradual tapering of the extensor digitorum brevis muscle distally can be appreciated here.*

PLANTAR MUSCLES, SUPERFICIAL LAYERS



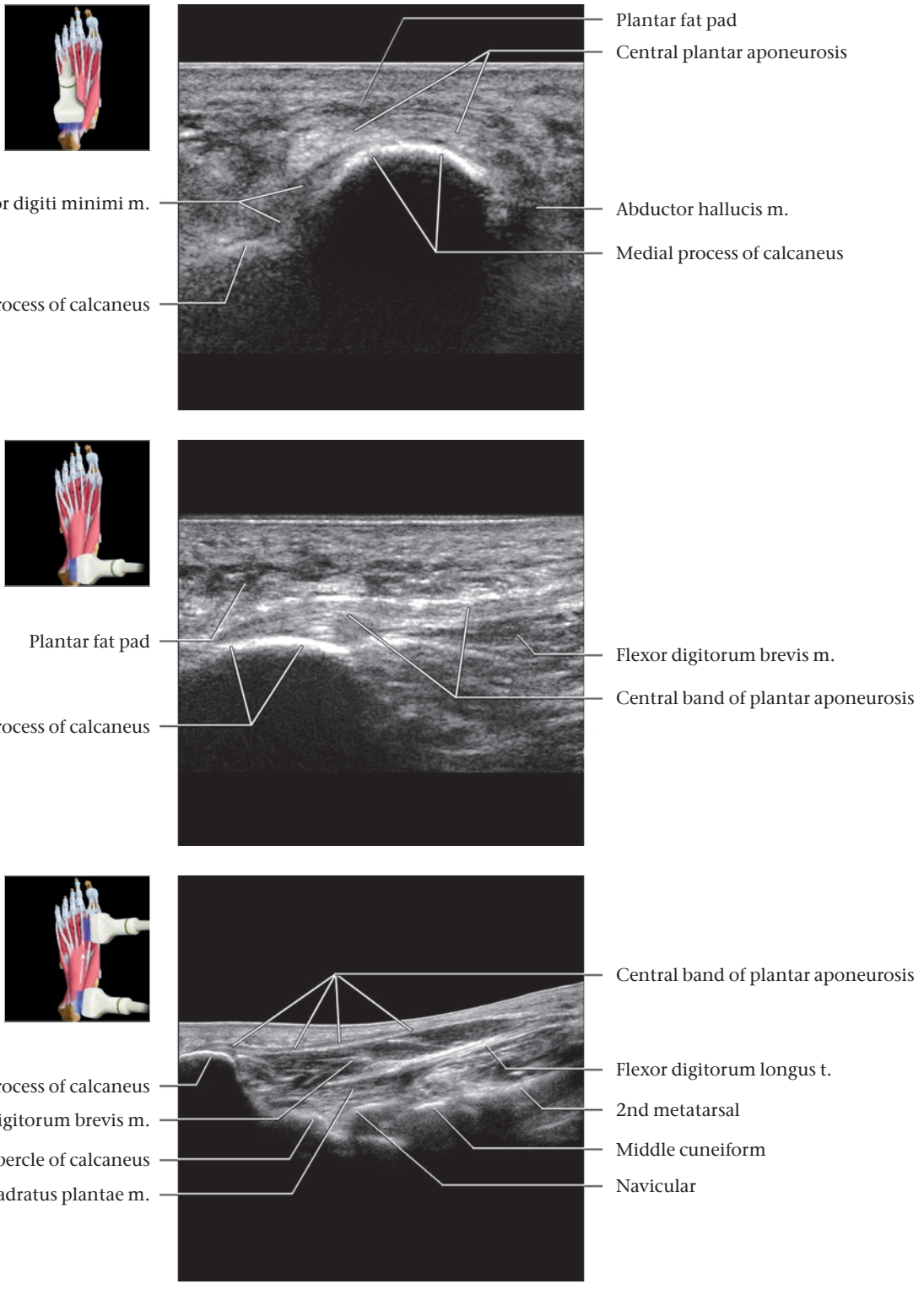
(Top) *Graphic shows the superficial layer of the plantar foot muscles: Abductor digiti minimi, flexor digitorum brevis, and abductor hallucis. The deep muscles are partially visible deep to the superficial layer. The flexor digitorum brevis tendons split in each digit (4th digit labeled), attaching at lateral aspects of the middle phalangeal bases. The flexor tendon sheaths hold the flexor mechanism in close proximity to the phalanges.* ***(Bottom)*** *Graphic shows the 2nd layer of plantar muscles. The interesting arrangement of interactions between flexors is well seen: Quadratus plantae inserting on flexor digitorum longus tendon and lumbricals arising from individual flexor digitorum longus tendon slips. In the toes, the flexor tendons are contained within fibrous tendon sheaths.*

PLANTAR FOOT MUSCLES, DEEP LAYERS



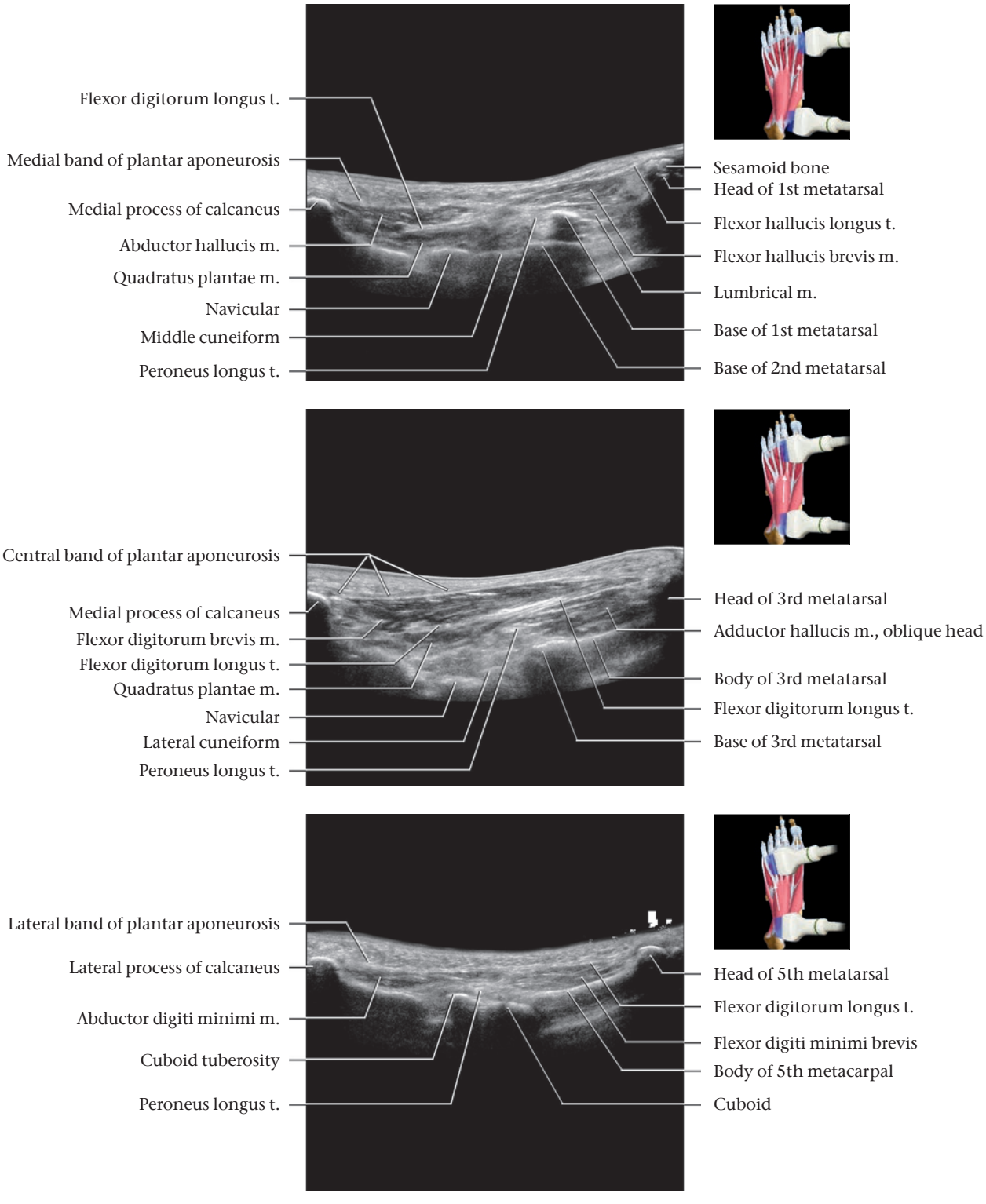
(Top) *Graphic shows the 3rd layer of plantar muscles. This layer contains the flexor hallucis brevis and flexor digiti minimi, as well as the adductor hallucis muscle. The oblique head of the adductor hallucis is thick and broad, whereas the transverse head is thin.* ***(Bottom)*** *Graphic shows the 4th layer of plantar muscles, the interosseous muscles. There are 4 dorsal interossei. They have bipennate origins from 2 adjacent metatarsals. There are 3 plantar interossei. The 1st plantar interosseous muscle originates from the medial side of the 3rd metatarsal and inserts on the medial side of the 3rd proximal phalanx. The 2nd and 3rd plantar interossei originate on the medial sides of the 4th and 5th metatarsals, respectively, and insert on the medial side of the corresponding proximal phalanx.*

PLANTAR APONEUROSIS



(Top) *Transverse scan of the calcaneus shows the origin of the plantar aponeurosis. The plantar aponeurosis fascia consists of 3 parts: Strong, thick central band over the flexor digitorum brevis muscle; lateral band over the abductor digiti muscle; thin medial band over the abductor hallucis muscle.* ***(Middle)*** *Sagittal scan shows the origin of the central band of the plantar aponeurosis. This arises from the medial process of the calcaneus and runs anteriorly deep to the plantar subcutaneous fat.* ***(Bottom)*** *Sagittal panoramic scan shows the central band of plantar aponeurosis. The central is the thickest and most easily identified component of the plantar aponeurosis. Deep to this are the flexor digitorum brevis and quadratus plantae muscles, which form the bulk of the central tarsal plantar compartment.*

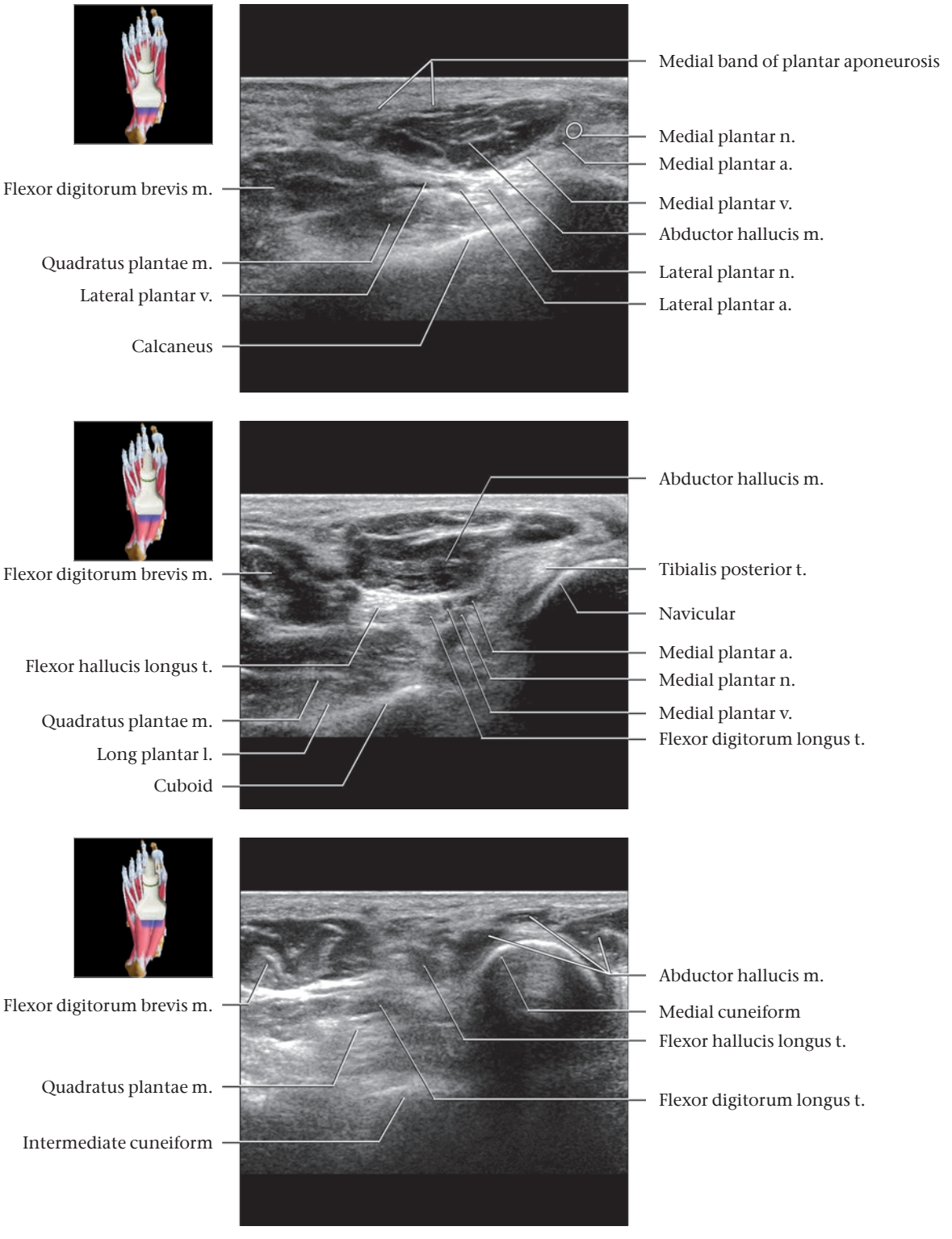
SAGITTAL FOOT OVERVIEW



(Top) *Series of 3 panoramic sagittal scans are shown through the plantar aspect of the foot. This scan shows the content of the medial compartment: The abductor hallucis muscle, flexor hallucis longus tendon, and flexor hallucis brevis muscle, together with smaller structures.* ***(Middle)*** *In the central plantar compartment, the contents can be divided into layers. Superficially, there is the flexor digitorum brevis muscle and the flexor digitorum longus tendon. Deep to this layer are the quadratus plantae muscle, oblique head of the adductor hallucis muscle, and the lumbricals.* ***(Bottom)*** *A scan through the lateral compartment is seen containing the abductor digiti minimi muscle and the flexor digiti minimi muscle.*

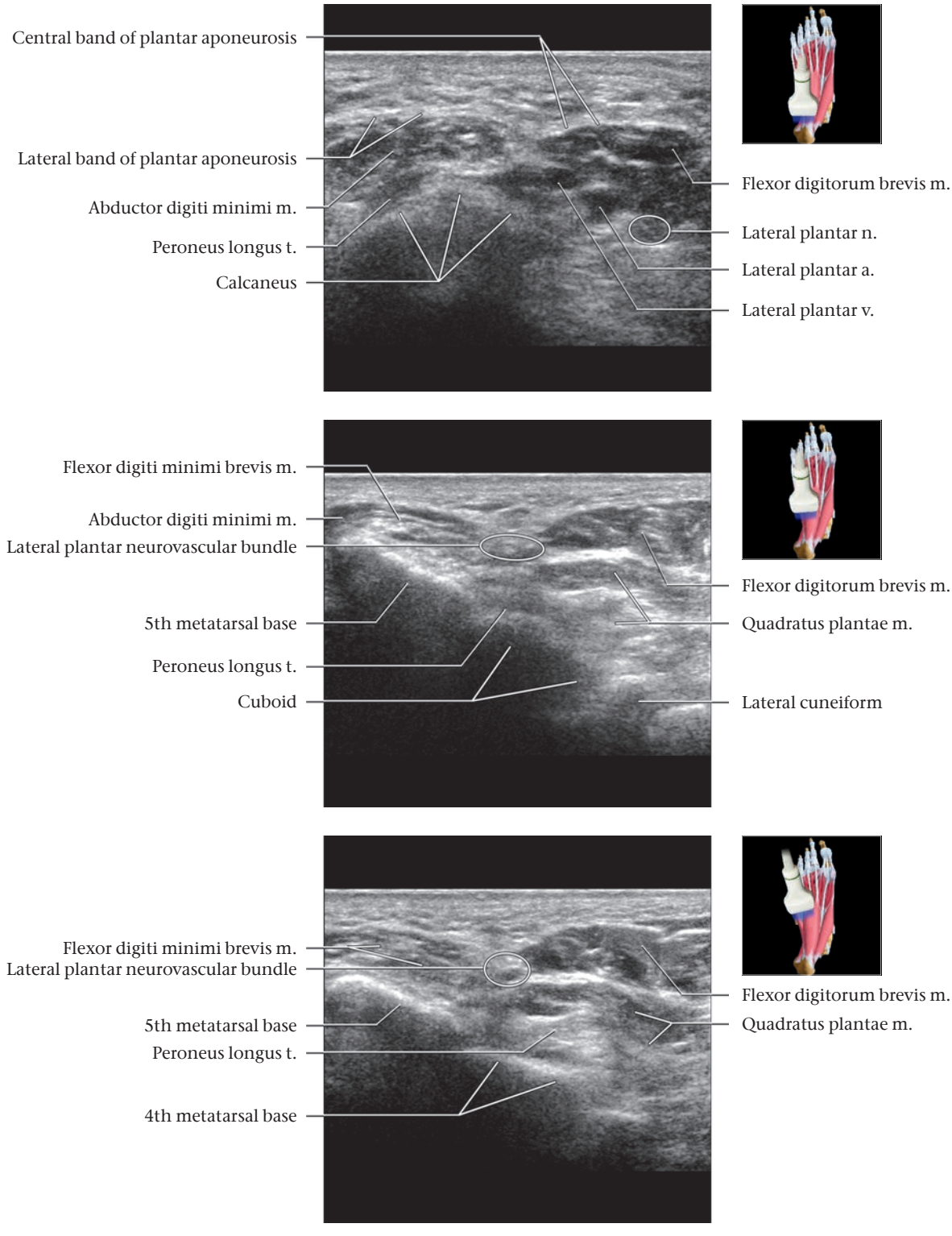
TARSUS

MEDIAL TARSUS



(Top) *Series of 3 coronal scans are shown through the medial 1/2 of the plantar aspect of the foot. At this proximal level, the 2 main muscles (flexor digitorum brevis and quadratus plantae) of the central compartment can be seen lying superficial to the calcaneus. The medial compartment muscle (abductor hallucis) can also be seen medially.* ***(Middle)*** *At the level of the midtarsus, the knot of Henry can be seen. This is where tendons of the flexor digitorum longus and flexor hallucis longus tendons cross and exchange fibers. The medial plantar neurovascular bundle lies in close proximity to this.* ***(Bottom)*** *More distally, the flexor hallucis longus and digitorum longus tendons separate and head toward their respective insertions.*

LATERAL TARSUS



(Top) *Series of 3 coronal scans are shown through the lateral 1/2 of the plantar aspect of the foot. The lateral compartment (abductor digiti minimi) and 1/2 of the central compartment can be seen here, separated by the lateral plantar neurovascular bundle. The calcaneus forms the bony support of all structures at this level.* ***(Middle)*** *At the level of the midtarsus, the separation between the lateral and the central compartment by the neurovascular bundle continues. Within the lateral compartment, the abductor digiti minimi muscle moves laterally, to give way to the other component of the lateral compartment, the flexor digiti minimi brevis muscle.* ***(Bottom)*** *Most distally, the abductor digiti minimi muscle runs on the lateral border, and only the flexor digiti minimi brevis muscle is seen on the plantar aspect of the foot.*

FOOT VESSELS

IMAGING ANATOMY

Arteries

- **Dorsalis pedis artery**
  - Dorsal artery of foot
  - Direct continuation of anterior tibial artery, changing name at ankle joint
  - Course and relations
    - Crosses superficial to talocrural articular capsule, talus, navicular, and intermediate cuneiform bones
    - Passes deep to inferior extensor retinaculum and distal to extensor hallucis brevis
    - Lies lateral to extensor hallucis longus tendon
    - Passes to proximal end of intermetatarsal space and curves deeply to enter sole between heads of 1st dorsal interosseous muscle
    - Forms part of plantar arch
  - Main branches
    - Medial and lateral tarsal arteries: Arise at level of navicular bone
    - Lateral tarsal artery runs under extensor digitorum brevis
    - 2 or 3 medial tarsal arteries run on medial surface of tarsus
  - Arcuate artery: Arises at medial cuneiform level and runs laterally over metatarsal bases, deep to extensor tendons; gives off branches to metatarsals and toes
  - 1st dorsal metatarsal artery: Arises just before dorsalis pedis dives deep into sole
- **Posterior tibial artery**
  - Continuation of calf vessel by same name, a branch of popliteal artery
  - Runs in tarsal tunnel behind and below medial malleolus accompanied by tibial nerve
  - Divides into terminal branches (medial and plantar arteries) in tarsal tunnel
  - Medial plantar artery: Runs in medial aspect of foot medial to medial plantar nerve
    - Then deep to abductor hallucis and flexor digitorum brevis muscles
  - Lateral plantar artery: Runs in lateral aspect of foot lateral to the lateral plantar nerve
    - Then deep to abductor hallucis muscle and distally between flexor digitorum brevis and quadratus plantae muscles
    - Runs distally between flexor digitorum brevis and abductor digiti minimi, then runs between base of 1st and 2nd metatarsals, and finally joins dorsalis pedis to form plantar arch
- **Plantar arch**
  - Arterial arch at level of metatarsals
  - Formed by dorsalis pedis and lateral plantar arteries
  - Gives off branches to metatarsals and toes
- **Peroneal artery**
  - Accompanies superficial peroneal nerve down anterolateral aspect of ankle and sends off perforating branch that joins communicating branch from anterior tibial artery
  - May join or replace posterior tibial artery

Veins

- Superficial veins
  - Great saphenous vein
    - Arises from medial part of dorsal venous arch of foot
    - Runs subcutaneously over muscles and tendons to pass anterior to medial malleolus
    - Passes superiorly on medial aspect of calf and thigh to join common femoral vein at femoral triangle
  - Small saphenous vein
    - Arises from lateral part of dorsal venous arch
    - Runs subcutaneously over muscles and tendons to pass posterior to lateral malleolus
    - Passes superiorly on lateral and posterior side of calf to join popliteal vein in popliteal fossa
- Deep veins
  - Plantar venous arch: Receives venous drainage from dorsal and plantar aspects of toes and metatarsals
  - Medial and lateral plantar veins: Arise from plantar venous arch to accompany same named arteries
  - Communication exists with great and small saphenous veins
  - Medial and lateral plantar veins form posterior tibial veins in tarsal tunnel and run proximally to calf, accompanying posterior tibial artery

ANATOMY IMAGING ISSUES

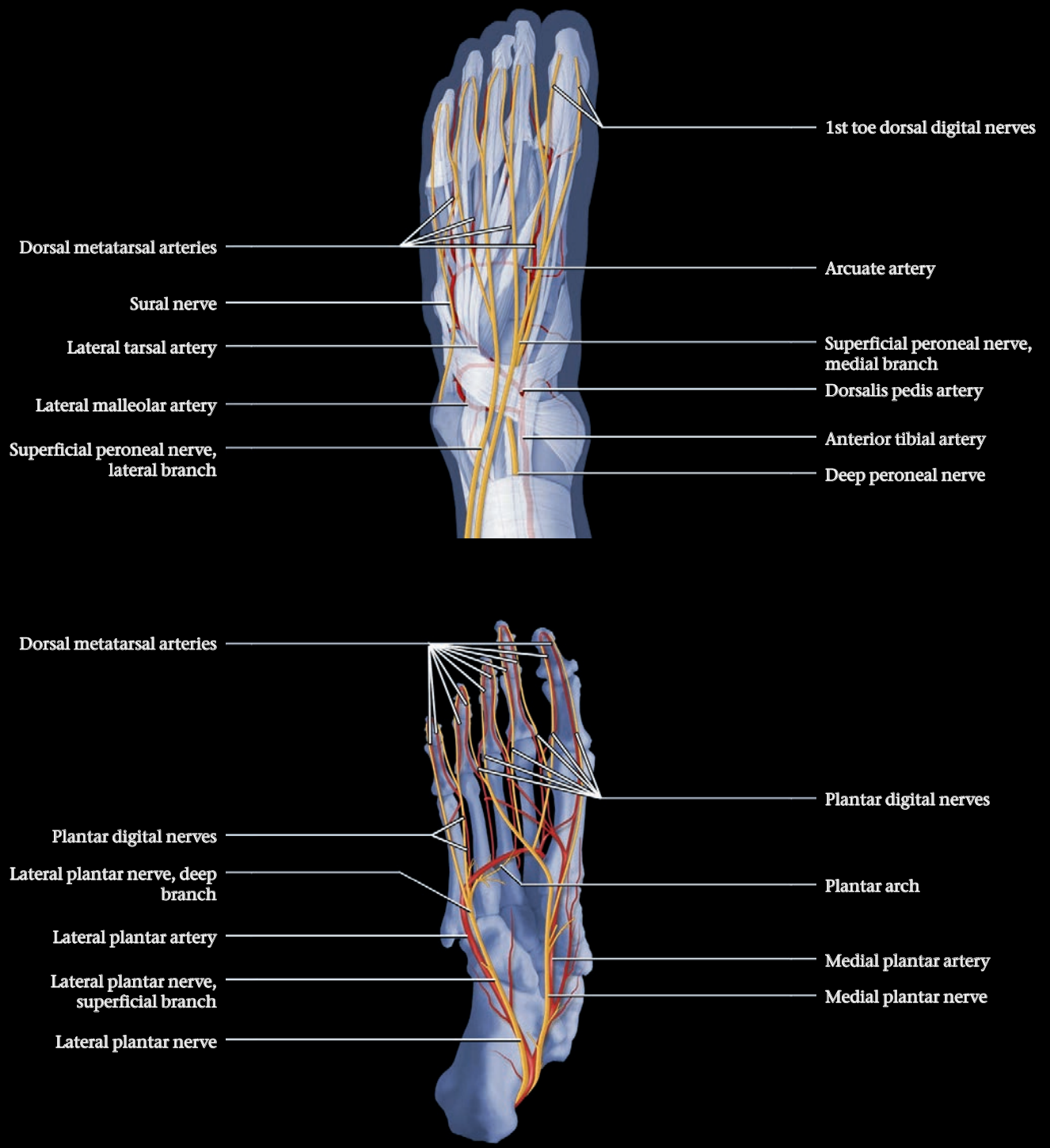
Imaging Recommendations

- US
  - Provides greatest amount of information on vasculature of foot of different imaging modalities available
  - Morphology and functional status of vessels can be assessed
  - Color Doppler scans allow assessment for vessel occlusion and thrombosis
  - Spectral Doppler scans allow quantitative and semiquantitative documentation of flow velocity, resistance, waveform, etc.
  - Augmentation of foot veins usually only requires small degrees of flexion/extension of toes to produce enough venous flow for detection (unlike need to squeeze muscles in calf)

Imaging Pitfalls

- Superficial veins are easily compressed even with lightest transducer pressure
  - Thick layer of coupling gel helps act as a spacer between transducer and skin to minimize pressure and allows for better visualization of vessels

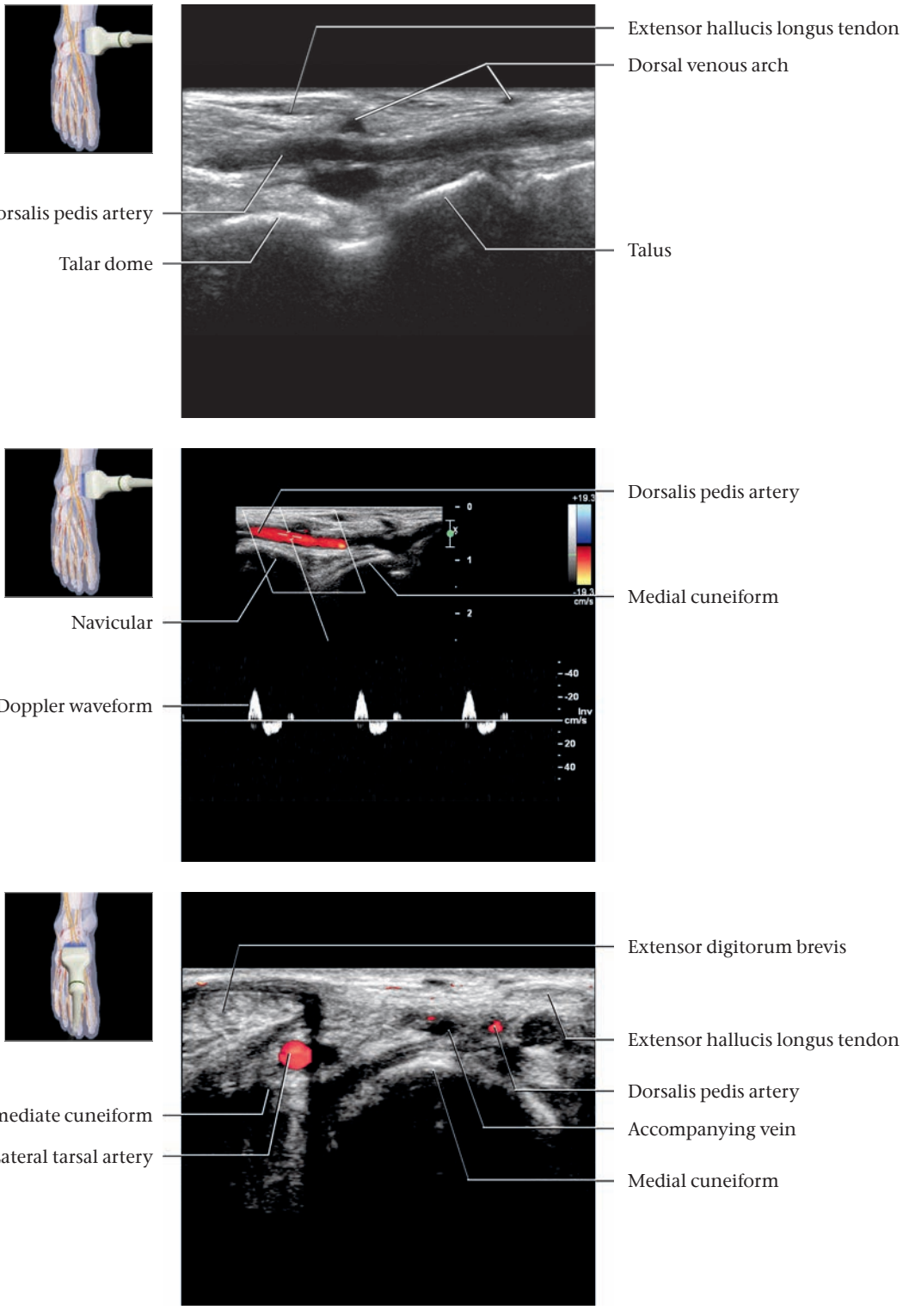
GRAPHICS, DORSAL AND PLANTAR ARTERIES AND NERVES



(Top) *Graphic shows arteries and nerves at the dorsal aspect of the foot. The deep peroneal nerve accompanies the anterior tibial artery. The superficial peroneal nerve divides into medial and lateral branches in distal 1/3 of leg. Anterior tibial artery is called dorsalis pedis in foot. It terminates in arcuate artery, which communicates with plantar arterial arch, and in digital vessels.* ***(Bottom)*** *Graphic shows arteries and nerve at the plantar aspect of the foot. The posterior tibial nerve and artery divide into medial and lateral plantar branches. These divide further into digital branches to the medial and lateral aspects of each toe. The plantar arch sends vessels dorsally as well as to the plantar aspect of the toes.*

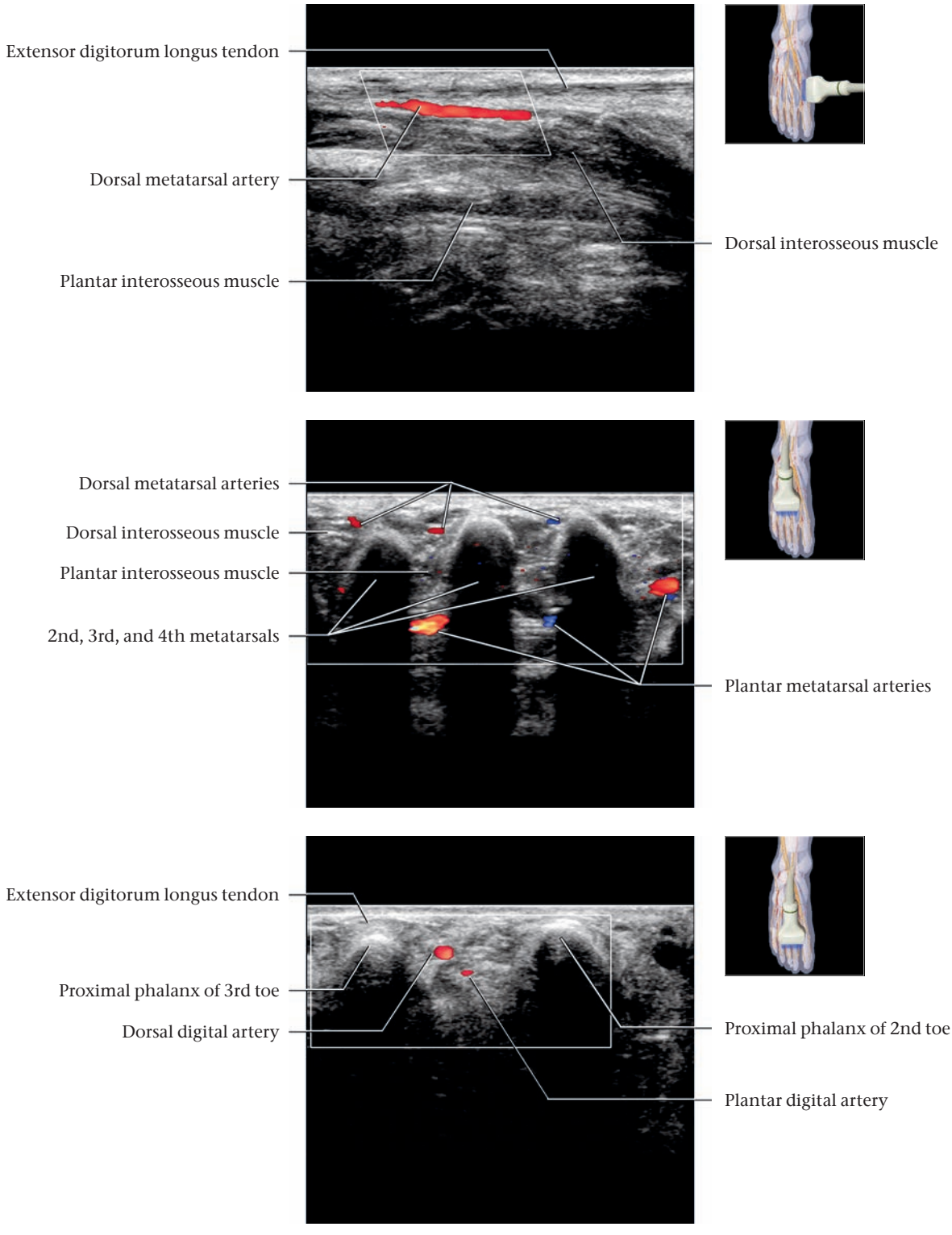
FOOT VESSELS

DORSALIS PEDIS ARTERY



(Top) *Sagittal scan shows the dorsum of the foot. The dorsalis pedis artery runs at the anterior aspect of the transverse arch formed by the tarsal bones. It is a continuation of the anterior tibial artery and runs lateral to the extensor hallucis longus tendon.* ***(Middle)*** *Sagittal spectral Doppler scan of the dorsalis pedis artery shows the typical triphasic artery flow.* ***(Bottom)*** *Coronal color Doppler scan shows the dorsum of the foot at the level of the cuneiform. The dorsalis pedis artery gives rise to medial and lateral tarsal arteries at the level of the navicular. The dorsalis pedis artery remains lateral to the extensor hallucis longus tendon even at this distal level.*

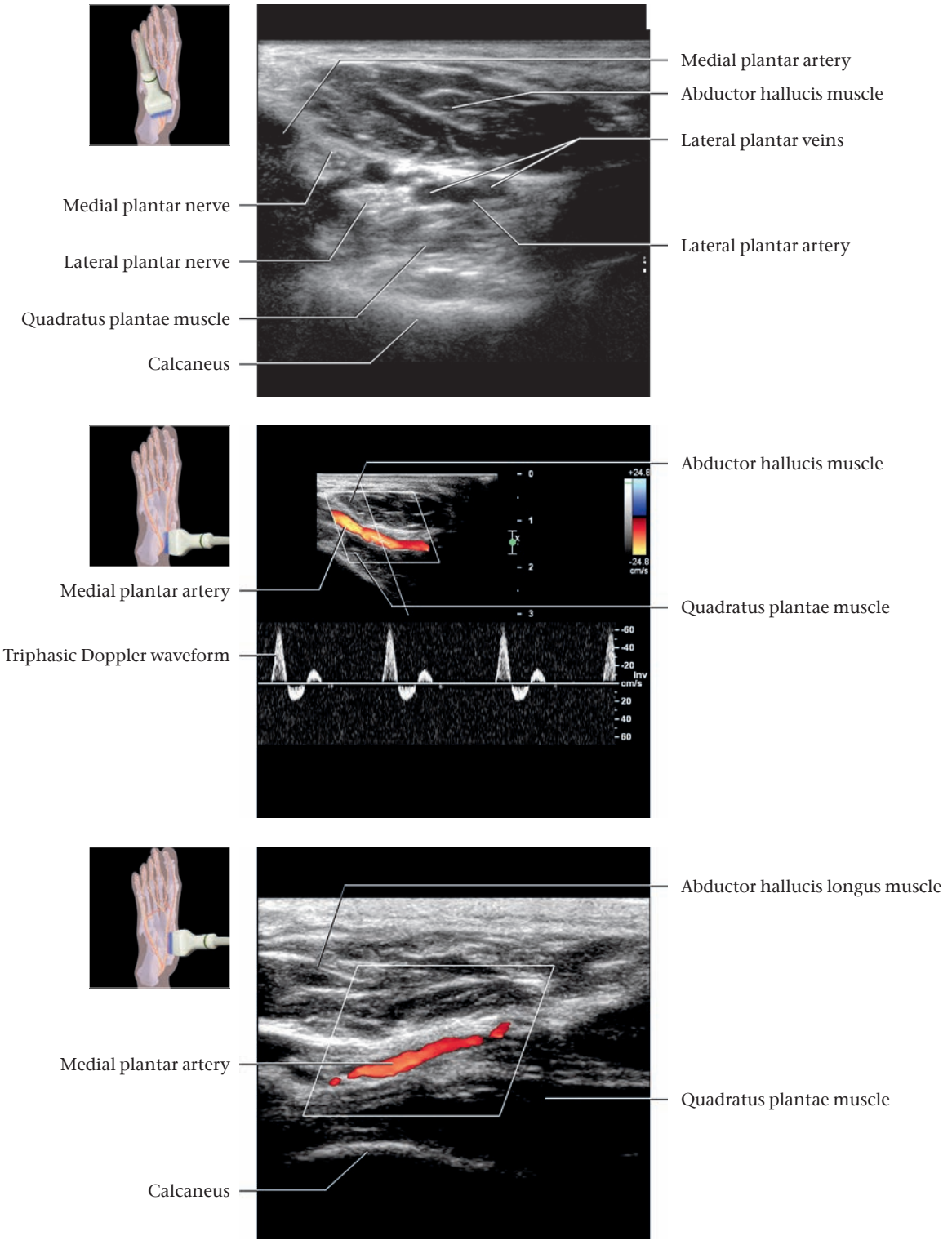
METATARSAL & DIGITAL ARTERIES



(Top) *Sagittal color Doppler shows the 2nd interosseous space. The arcuate artery gives rise to dorsal metatarsal arteries that run in the interosseous spaces to supply the metatarsals and toes. The 2 layers of interosseous muscles can be appreciated here.* ***(Middle)*** *Transverse color Doppler scan shows the metatarsal bodies. Both the dorsal and plantar interosseous muscles can be seen between the bones. The dorsal and plantar metatarsal arteries are also demonstrable by the use of color Doppler. The plantar metatarsal arteries arise from the plantar arch.* ***(Bottom)*** *Coronal color Doppler scan shows the 2nd web space. The dorsal and plantar metatarsal arteries continue distally as the digital arteries, which will divide further to run on the sides of the phalanges.*

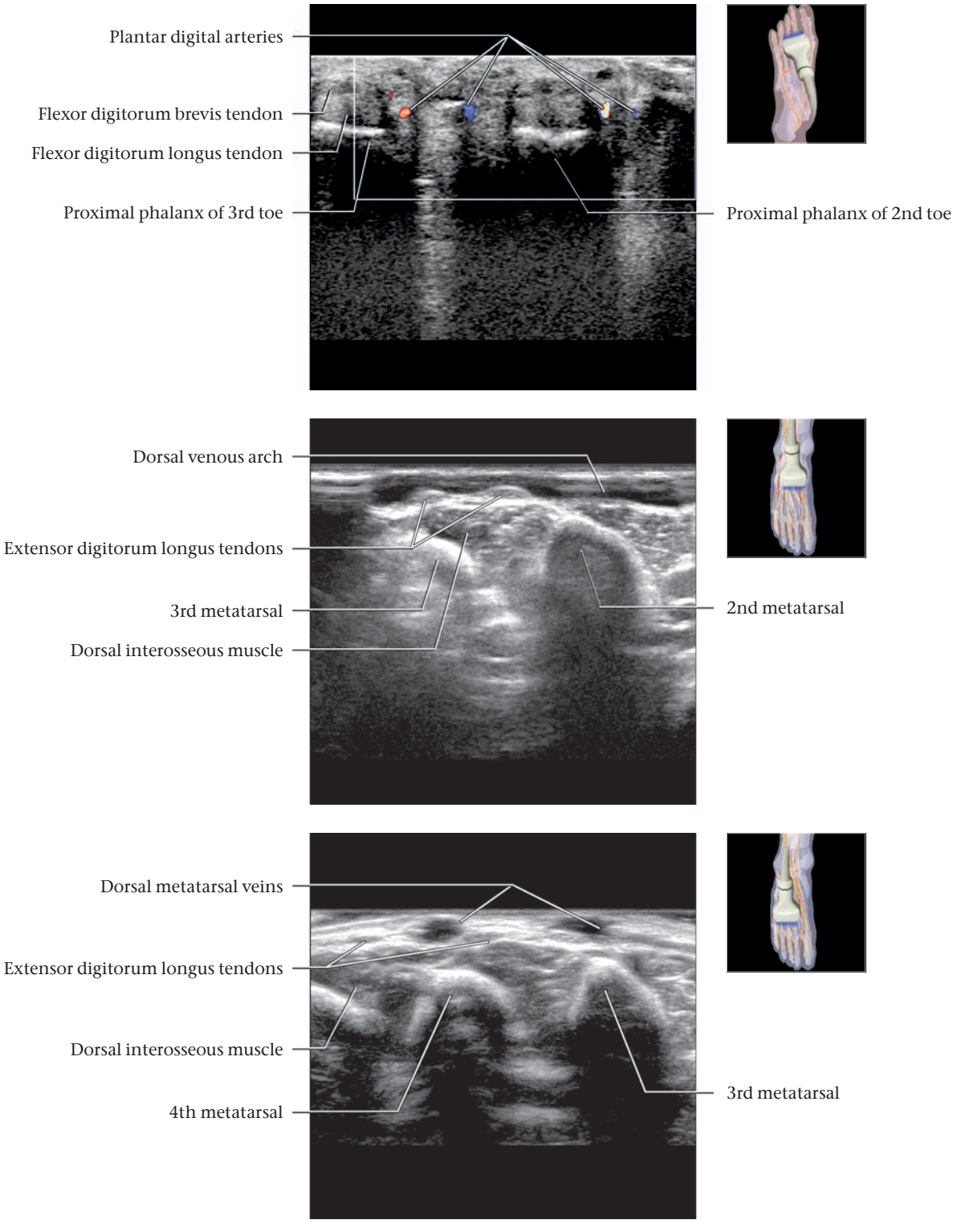
FOOT VESSELS

PLANTAR ARTERIES



(Top) *Coronal scan shows the medial plantar compartment. The tibial nerve has divided into the medial and lateral plantar nerves, and similarly, the posterior tibial vessels have divided into medial and lateral plantar vessels. Note that this is a scan of the left foot and the lateral side is on the right of the image.* ***(Middle)*** *Spectral Doppler scan of the medial plantar artery shows a typical triphasic arterial waveform.* ***(Bottom)*** *Oblique sagittal color Doppler scan of the medial compartment shows the medial plantar artery running between the abductor hallucis muscle and the quadratus plantae muscle.*

PLANTAR ARTERIES



(Top) *Coronal color Doppler scan shows the plantar aspect of the toes. The digital arteries can be seen on both sides of the phalanges as they travel more distally.* ***(Middle)*** *Coronal scan shows the dorsum of the foot at the metatarsal level. Minimal pressure was used during this scan to prevent compression of the superficial (subcutaneous) veins. Here, the transversely running dorsal venous arch is demonstrated. The extensor tendons and the interossei run deep to this arch.* ***(Bottom)*** *More distally, a coronal scan of the dorsum of the foot shows the tributaries of the dorsal venous arch, the dorsal metatarsal veins.*

METATARSALS AND TOES

IMAGING ANATOMY

Overview
- In normal weight-bearing stance, all metatarsal heads are at same level and all are weight bearing
  - Metatarsophalangeal (MTP) joints are slightly extended in standing position
- Each MTP joint is a separate synovial cavity

Metatarsal Bones
- 1st metatarsal
  - Largest metatarsal
  - Articulates with 1st cuneiform, 1st proximal phalanx, sesamoids
  - Medially receives attachments from tibialis anterior tendon, plantar side receives peroneus longus tendon
  - Origin of medial head of 1st dorsal interosseous muscle on its lateral surface
- 2nd-4th metatarsals
  - Gradually smaller and shorter moving laterally
  - Receive interosseous muscle on medial and lateral sides
- 5th metatarsal
  - Insertion of peroneus tertius and brevis

Phalanges
- Distal phalanx is insertion site for tendons from flexor and extensor digitorum longus
- Middle phalanx is insertion site for tendons from flexor and extensor digitorum brevis
- 2nd-4th proximal phalanges are attachments of interosseous muscles on both sides and lumbricals on medial side

1st MTP Joint
- Dorsiflexion of toe important in push-off phase of gait
- Metatarsal head has 2 concave facets at plantar surface, 1 for each sesamoid, separated by ridge (crista)
- Distal articular surface of metatarsal head may be flat, rounded, or have a central prominence
- Base of proximal phalanx has concave contour
- **Sesamoids**
  - Either sesamoid may be unipartite or bipartite
  - Medial sesamoid in medial head flexor hallucis brevis and abductor hallucis
  - Lateral sesamoid in lateral head flexor hallucis brevis and adductor hallucis and deep metatarsal ligament
  - Medial and lateral sesamoids joined by intersesamoid ligament
    - Intersesamoid ligament is floor of canal in which flexor hallucis longus tendon runs
  - Both are embedded in plantar plate of joint
  - **Sesamophalangeal apparatus**
    - Sesamoids fixed in position relative to 1st proximal phalanx, move relative to 1st metatarsal
    - Therefore, displaced laterally in hallux valgus
- **Plantar plate**
  - Fibrocartilaginous plantar capsular thickening extending from metatarsal neck to base of proximal phalanx
  - Incorporates sesamoids

Lateral MTP Joints
- Convex articular surface of metatarsal head articulates with concave articular surface of proximal phalangeal base
- Plantar aspect of metatarsal head has rounded contour
- Dorsal aspect of metatarsal head is smaller than plantar aspect
  - Has concave or notched contour along medial and lateral margins
- Sesamoids variably present, most commonly at 5th toe
- **Phalangeal apparatus** is combination of plantar plate and proximal phalanx
- **Plantar plate**
  - Fibrocartilaginous plantar capsular thickening extending from metatarsal neck to base of proximal phalanx
  - Attached to deep transverse metatarsal ligament, plantar fascia and flexor tendon sheath, medial and lateral collateral ligaments
  - Instability may mimic Morton neuroma

ANATOMY IMAGING ISSUES

Imaging Recommendations
- Ultrasound
  - Good for assessing tendon integrity and joint alignment
    - Tendon integrity recognized by morphology (continuity of tendon and densely packed appearance of tendon fibers) and by behavior during passive movement
    - Joints can also be assessed dynamically during flexion and extension
  - Limited use in assessing for global bony alignment

CLINICAL IMPLICATIONS

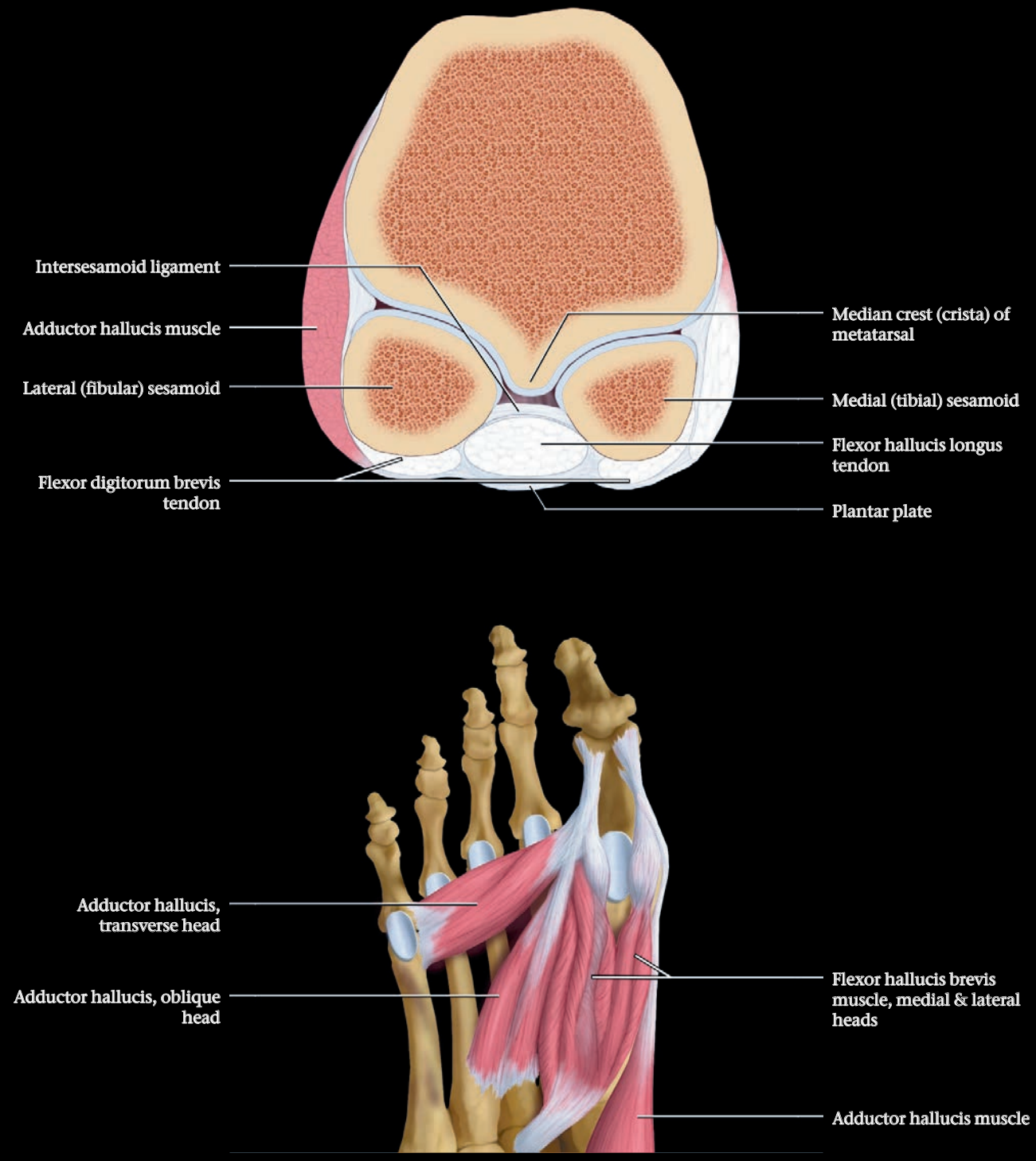
Clinical Importance
- Instability of MTP joints results in pain and deformity of forefoot

Stability of 1st MTP Joint
- Collateral ligaments
- Flexor and extensor hallucis brevis muscles
- Flexor and extensor hallucis longus have a smaller contribution to stability

Stability of Lateral MTP Joints
- Collateral ligaments
- Plantar plate
  - Rupture of plantar plate results in dorsal subluxation of MTP joint and hammer toe deformity

Short 1st Metatarsal (Morton Foot)
- Normal variant, but increases stress on 2nd metatarsal
- Predisposes to osteonecrosis of 2nd metatarsal head (Freiberg infraction)

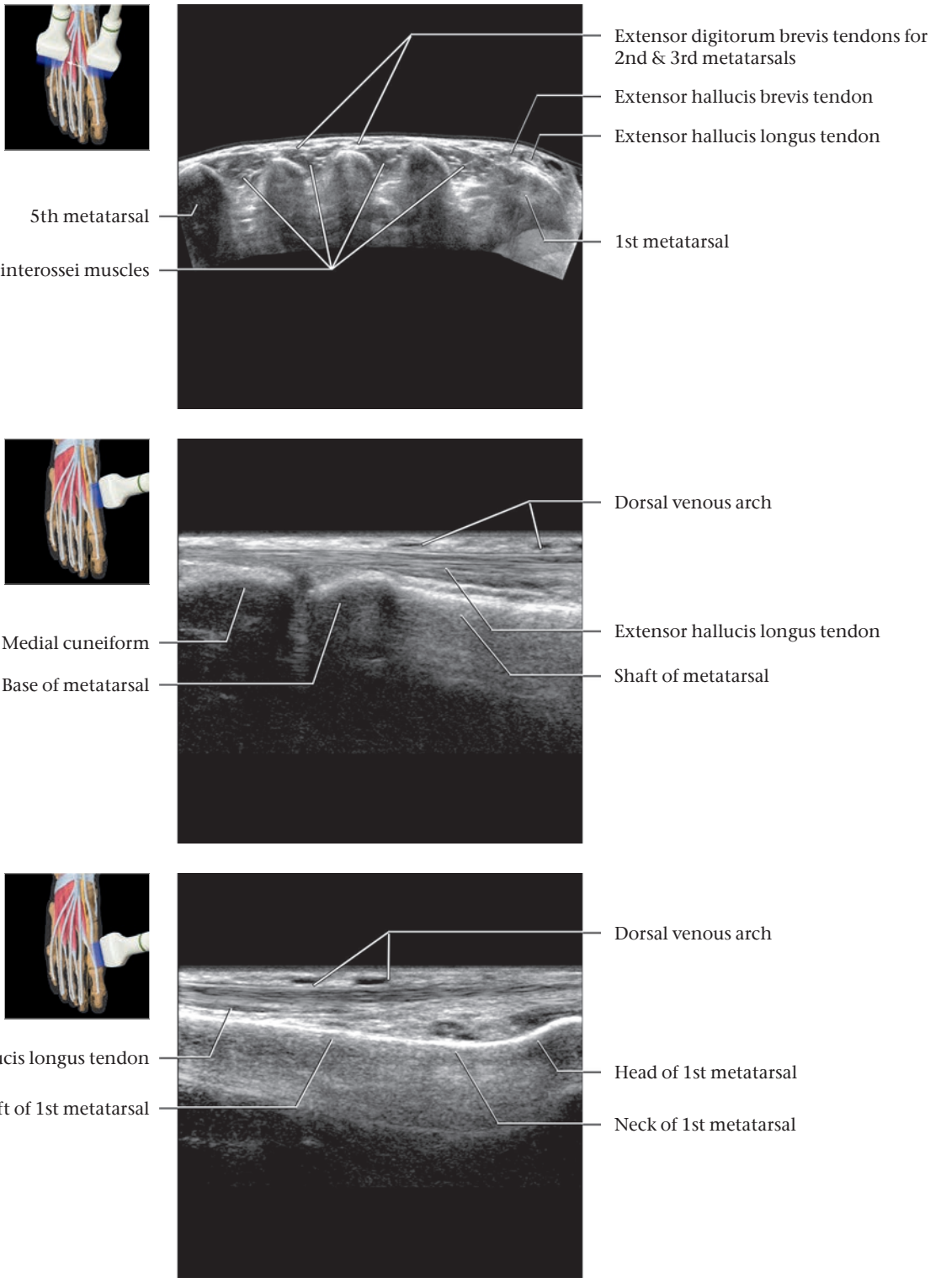
GRAPHICS, 1ST METATARSAL HEAD SECTION AND TOES



(Top) *Coronal (perpendicular to long axis of metatarsal bone) graphic shows sesamoid bone located on the plantar surface of the 1st metatarsal head, separated by the median crest of the metatarsal bone. The sesamoids are united by the intersesamoid ligament. The intersesamoid ligament forms the floor of the groove between the sesamoids; the flexor hallucis longus tendon runs along this groove.* ***(Bottom)*** *Axial graphic shows muscle attachments to sesamoids of the 1st metatarsophalangeal joint. Abductor hallucis and medial head of flexor hallucis brevis attach to medial sesamoid. Lateral head of flexor hallucis brevis and adductor hallucis attach to the lateral sesamoid.*

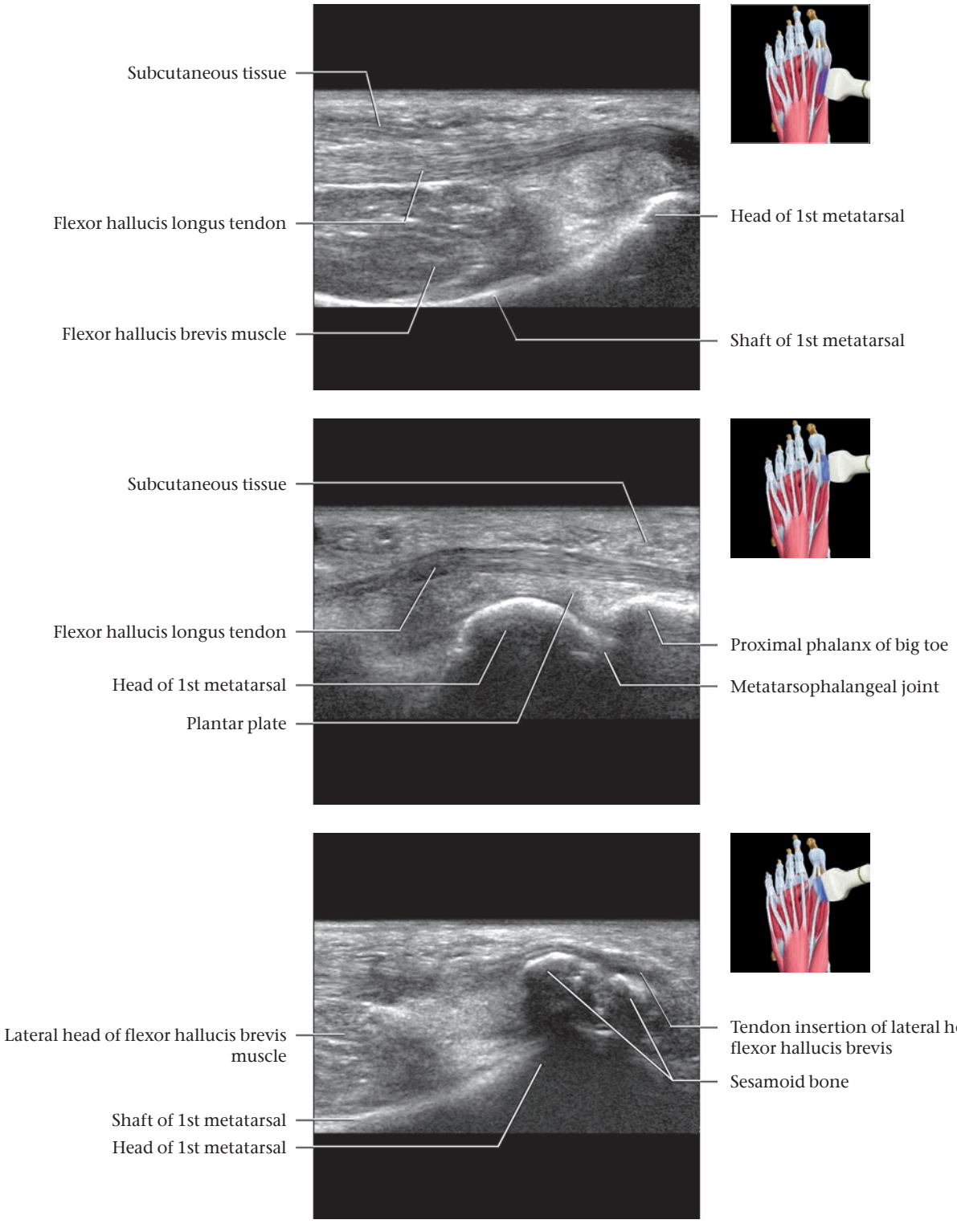
METATARSALS AND TOES

DORSUM METATARSAL



(Top) *Coronal panoramic scan shows the dorsal surface of the bodies of the metatarsals. The dorsal interosseous muscles lie between the bodies of the metatarsals. Their action is to abduct the toes. The plantar interosseous muscles act to adduct the toes. The extensor digitorum longus and extensor hallucis longus tendons receive assistance from their brevis tendons, which are deeper and approach from a lateral aspect.* ***(Middle)*** *Sagittal scan shows the dorsum of the big toe at the level of the tarsometatarsal joint. The extensor hallucis longus tendon is in close proximity to the bones around the joint. Note the densely packed and parallel echogenic tendon fibers.* ***(Bottom)*** *Sagittal scan shows the head of the 1st metatarsal. The extensor hallucis longus tendon is separated from the neck and most of the body of the metatarsal by fat.*

PLANTAR METATARSAL

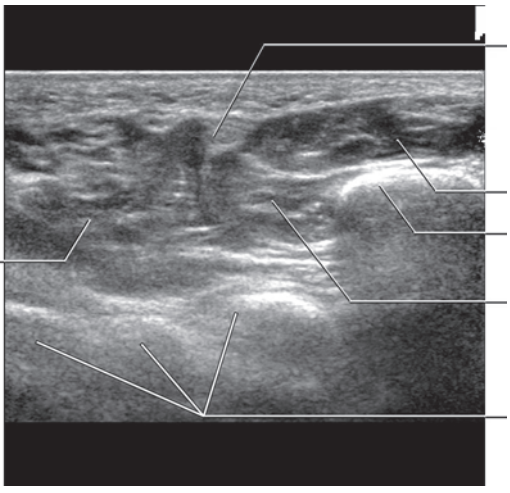


(Top) *Sagittal scan shows the plantar aspect of the head of the 1st metatarsal. The flexor hallucis longus muscle originates in the calf, while the brevis muscle arises from the cuboid and lateral cuneiform bones and tendon of the tibialis posterior.* ***(Middle)*** *Sagittal scan shows the center of the 1st metatarsophalangeal joint. The flexor hallucis longus tendon passes over the plantar plate of this joint to reach its insertion at the distal phalanx.* ***(Bottom)*** *Oblique sagittal scan shows the 1st metatarsophalangeal joint, just lateral to the center. The flexor hallucis brevis tendons insert on to both sides of the base of the proximal phalanx via 2 tendons. Each tendon contains a sesamoid bone. Sesamoid bones may be bipartite as seen here, especially for the medial sesamoid.*

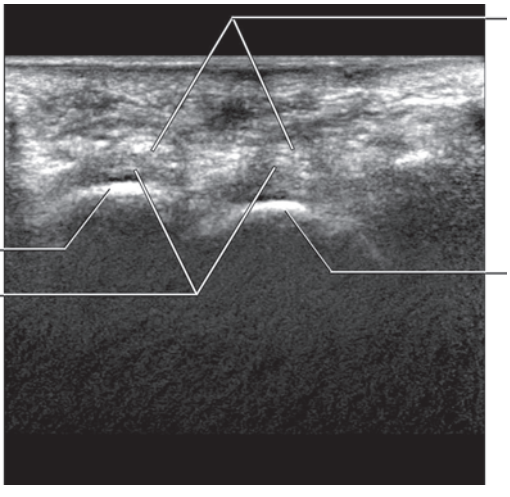
METATARSALS AND TOES

TRANSVERSE METATARSALS

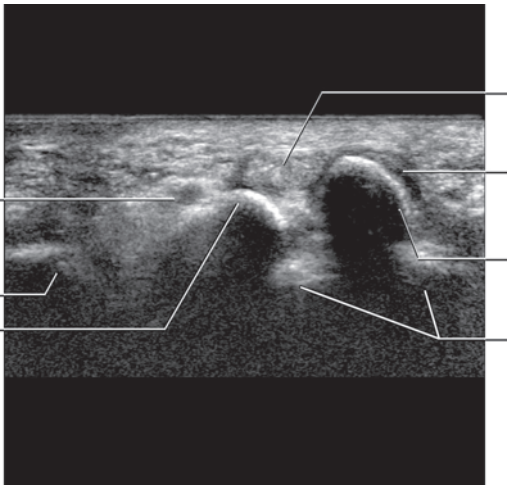




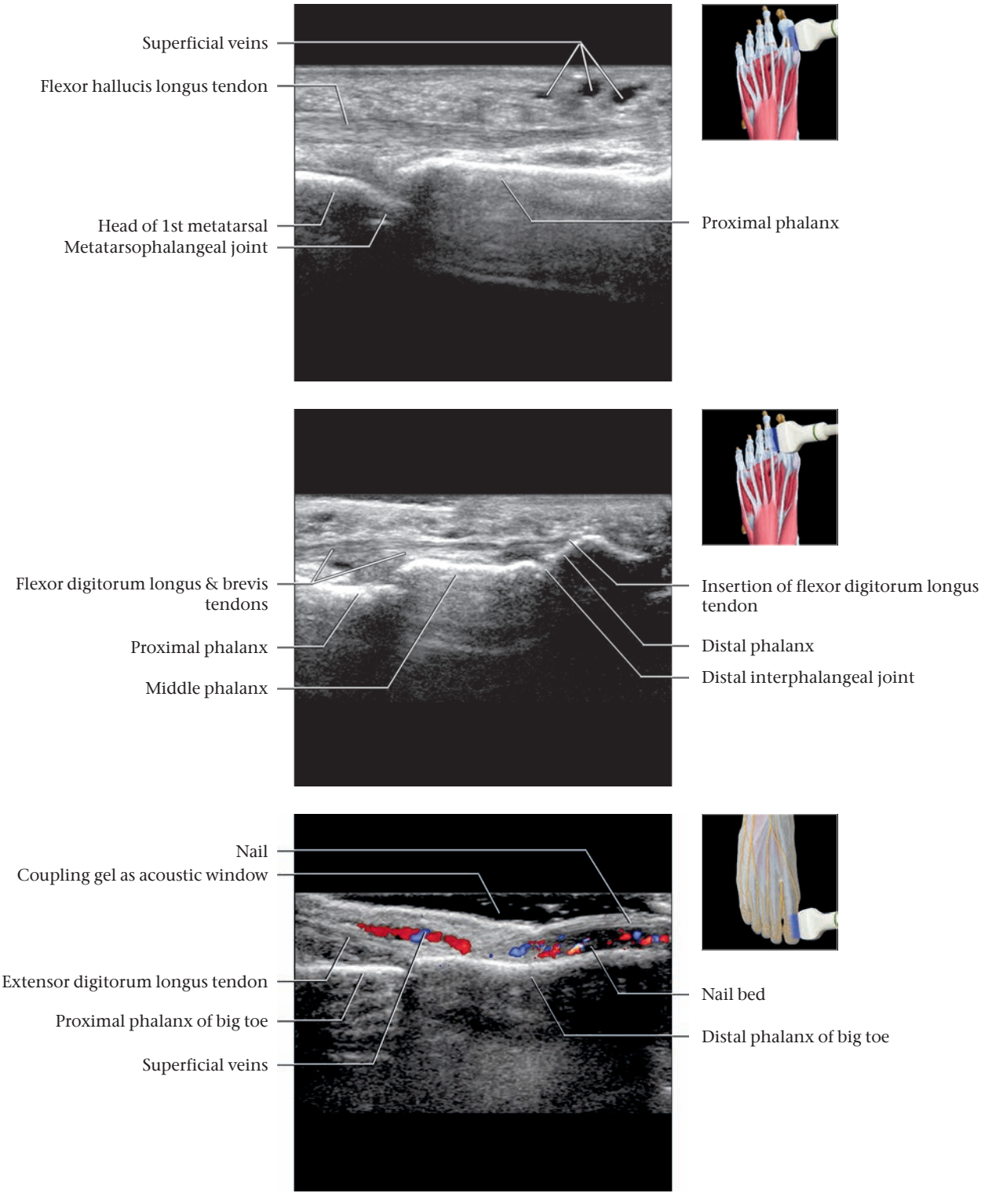




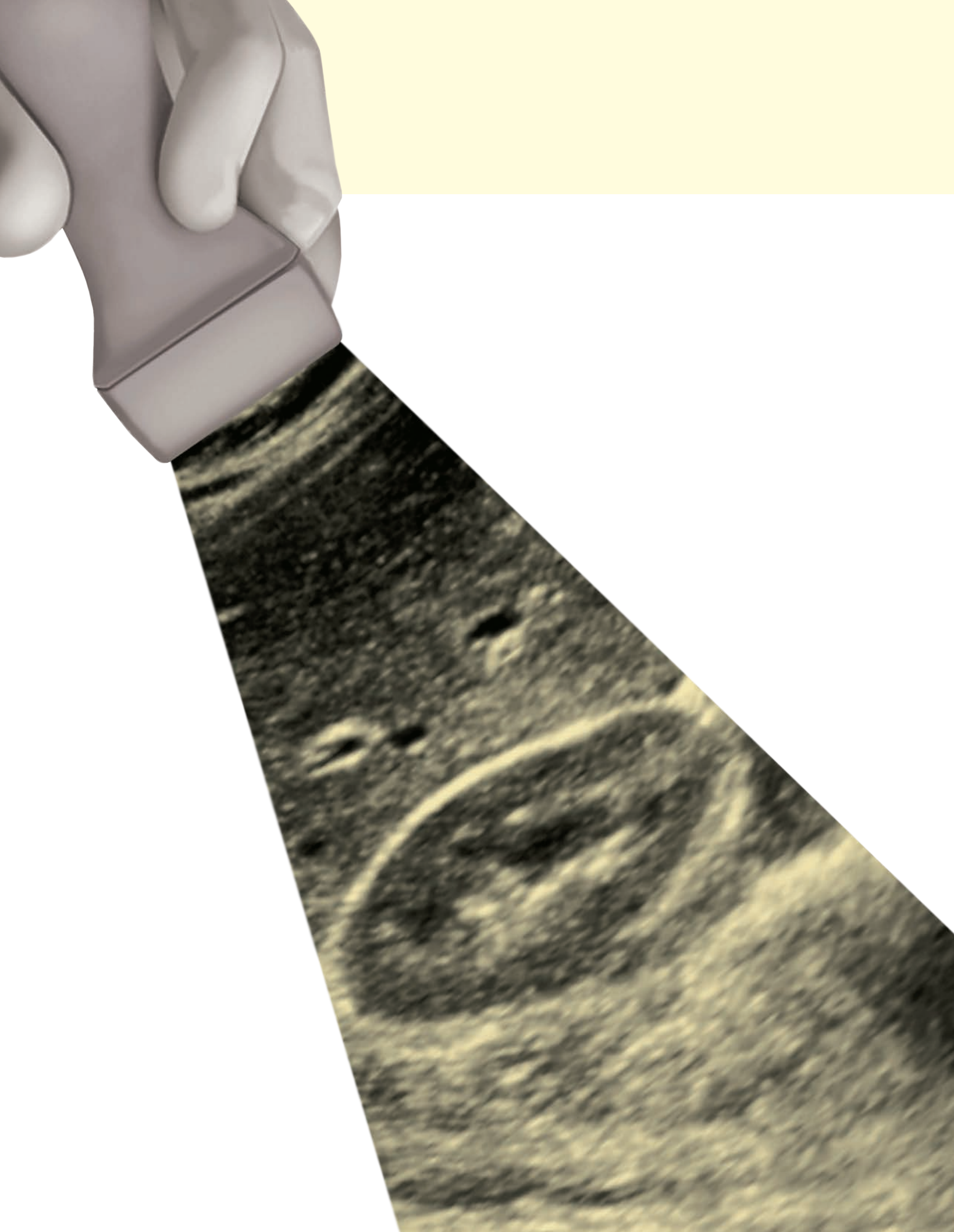




(Top) *Transverse scan shows the plantar aspect of the bases of the medial metatarsals. The abductor hallucis muscle is superficial to the 1st and 2nd metatarsals. The base of the 1st metatarsal is uniquely large compared to the rest of the metatarsals and is easily identifiable. The flexor hallucis longus tendon runs superficial to the brevis muscle.* ***(Middle)*** *Transverse scan shows the plantar surface of the base of the 2nd and 3rd metatarsals. The base of the metatarsals form an arch with plantar concavity. The flexor digitorum longus tendons run centrally on the plantar surfaces of the metatarsals.* ***(Bottom)*** *Transverse scan shows the plantar surface of the 1st metatarsal. The flexor hallucis longus runs between the 2 sesamoid bones on the plantar aspect of the 1st metatarsal. The sesamoids adhere to the medial and lateral heads of the flexor hallucis brevis tendons.*

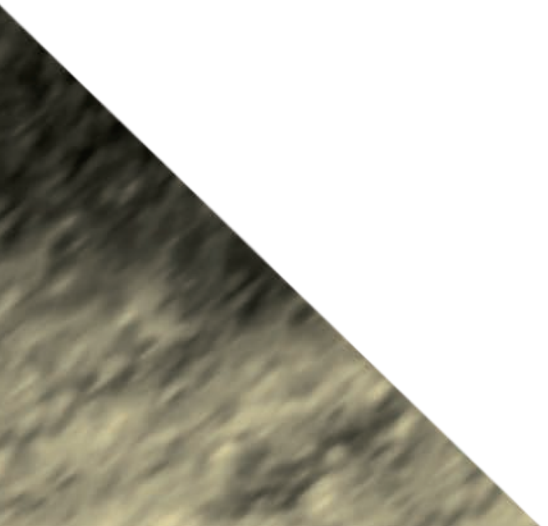


(Top) *Sagittal scan shows the plantar surface of the 1st tarsometatarsal joint. The flexor hallucis tendon runs close to the plantar surface of the phalanges and inserts at the base of the distal phalanx.* ***(Middle)*** *Sagittal scan shows the plantar surface of the 2nd toe. The flexor digitorum longus tendon inserts centrally at the base of the distal phalanx. The flexor digitorum brevis inserts on the sides of the base of the middle phalanx. Passive flexion of only the distal interphalangeal joint allows isolated evaluation of the tendon's movement (and integrity) of the flexor digitorum longus tendon.* ***(Bottom)*** *Sagittal color Doppler scan shows the dorsal surface of the distal phalanx of the big toe. The extensor digitorum longus tendon inserts on the dorsal surface of the base of the distal phalanx. The nail bed has a rich vascular supply as demonstrated by the color flow.*



SECTION 3
Trunk

Brachial Plexus **I**-3-2
Ribs and Intercostal Space **I**-3-8
Abdominal Wall and Paraspinal Structures **I**-3-12
Groin **I**-3-24
Gluteal Muscles **I**-3-34



BRACHIAL PLEXUS

GROSS ANATOMY

Ultrasound Anatomy

- Brachial plexus (BP)
  - Major neural supply to upper limbs
  - Formed from C5-T1 roots combining to form 3 trunks, 6 divisions, 3 cords, and 5 motor/sensory terminal branches (classic description)
    - 5 motor/sensory terminal branches are ulnar, median, musculocutaneous, axillary, and radial nerves
  - In reality, up to 30 variations on this classic pattern exist with no predominant pattern
    - Cannot rely on having definite number of trunks, divisions, or cords at any particular location
- 5 specific areas should be assessed
  - **Extraforaminal area (5 roots)**
    - Single large fascicle arising from spinal cord levels C5 to T1
    - Divides and recombines along length of brachial plexus
    - Epineurium is thin proximally and becomes thicker more distally along brachial plexus
  - **Intrascalene area (5 roots → 3 trunks)**
    - Posterior to clavicular head of sternocleidomastoid muscle between scalenus anterior muscle anteromedially and scalenus medius muscle posterolaterally
    - Roots are present in superior interscalene area proximally
    - C5 and T1 roots are more difficult to see due to their deep location
    - Roots unite to form trunks in inferior interscalene area distally
    - Upper (C5-6), middle (C7), lower (C8, T1) trunks
    - Average cross-sectional area of these trunks is 0.07 cm^2 (upper), 0.09 cm^2 (middle), and 0.09 cm^2 (lower)
    - Upper and middle trunks are cephalad and posterior to subclavian artery
    - Upper (C5-6) trunk or part of it may run through or anterior to anterior scalene muscle
    - Lower trunk is posterior to subclavian artery and can be more difficult to see because of its depth
    - Deep cervical artery runs posteriorly between middle and lower trunks
    - Minor nerves arising directly from trunks: Suprascapular nerve and nerve to subclavius muscle
    - Brachial plexus enters supraclavicular fossa by emerging between scalenus anterior and medius muscles
  - **Supraclavicular area (6 divisions)**
    - Trunk divides into anterior and posterior divisions in supraclavicular fossa
    - Lie superoposterior and lateral to subclavian artery ("bunch of grapes")
    - Anterior divisions innervate anterior (flexor) muscles
    - Posterior divisions innervate posterior (extensor) muscles
    - Transverse cervical artery runs laterally in this region, usually below divisions of brachial plexus
  - **Infraclavicular area (3 cords)**
    - Passageway between supraclavicular fossa and apex of axilla
    - About 3 cm inferomedial to coracoid process, cords position themselves lateral, medial, and posterior to axillary artery
    - Lateral cord innervates anterior (flexor) muscles
    - Medial cord innervates anterior (flexor) muscles
    - Posterior cord innervates posterior (extensor) muscles
    - Posterior cord is most difficult to see as it lies posterior to brachial artery
    - Cords tend to be more hyperechoic than hypoechoic trunks or divisions as brachial plexus contains an increasing number of fascicles and more connective tissue distally
    - Overlying the cords is pectoralis major muscle medially, pectoralis minor muscle laterally, while serratus anterior covers chest wall medially
  - **Axillary area (5 terminal branches)**
    - Pyramidal space beneath glenohumeral joint
    - Lateral cord → median nerve and musculocutaneous nerve (C5-6)
    - Medial cord → median nerve and ulnar nerve (C8-T1)
    - Posterior cord → axillary nerve (C5-6), radial nerve (C5-T1), thoracodorsal nerve (C6-8) as well as upper (C6-7) and lower (C5-6) subscapular nerves
    - Both lateral and medial cords contribute to median nerve
    - Nerves are arranged around axillary artery with ulnar nerve at 2-3 o'clock, radial nerve at 5-6 o'clock, and median nerve at 10-11 o'clock
    - Median, ulnar, and radial nerves are enclosed within a sheath separate from musculocutaneous nerve
    - In most cases, musculocutaneous nerve branches early from lateral cord
    - Musculocutaneous nerve is easily seen by moving probe over medial bicipital groove proximally where nerve is seen between coracobrachialis and biceps muscles
    - Musculocutaneous nerve then descends along lateral side of arm between biceps and brachialis muscles

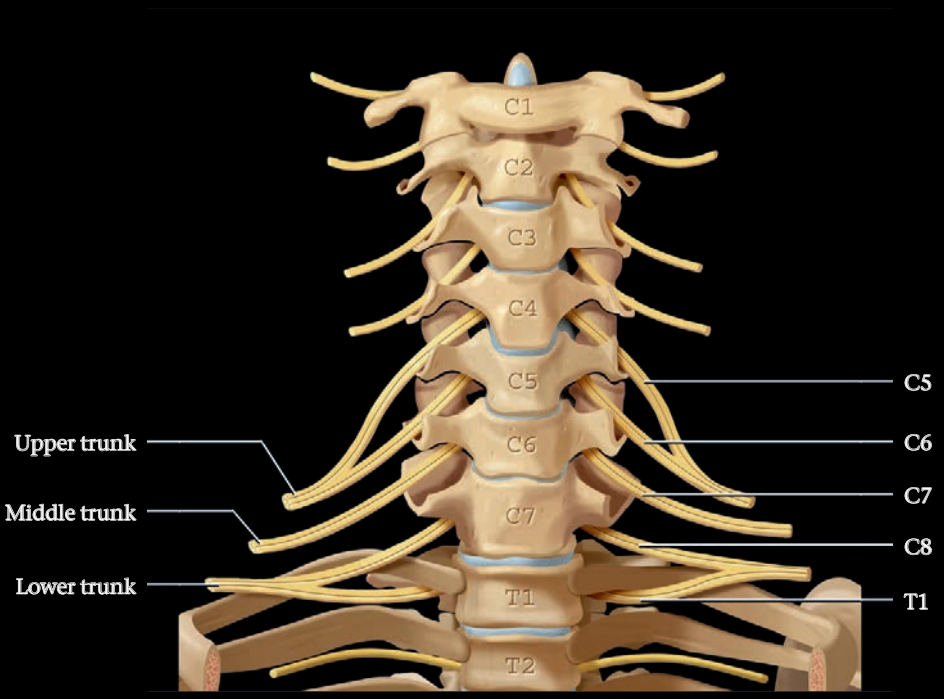
ANATOMY IMAGING ISSUES

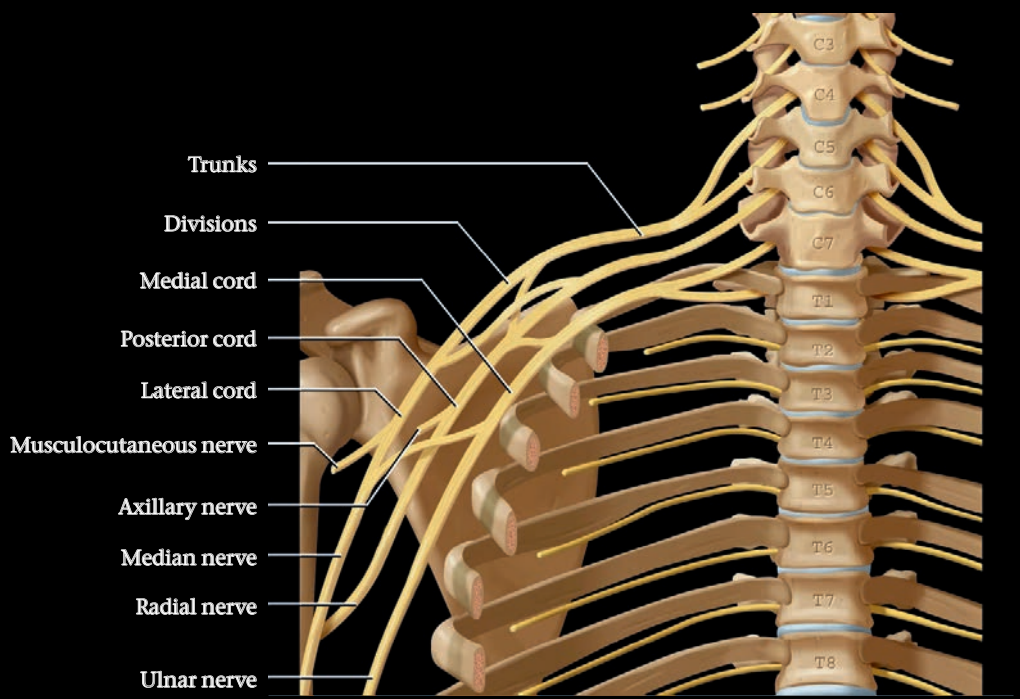
Imaging Approaches

- Ultrasound is most efficient way of seeing brachial plexus as perineural fat allows good visualization of nerves
- Best to evaluate brachial plexus on transverse scanning though roots also well seen on longitudinal scanning
- Routinely evaluate each of the 5 designated areas
- Color Doppler imaging helps distinguish brachial plexus from vascular structures
- Infraclavicular portion of brachial plexus is the least well seen on ultrasound as it is covered by pectoralis muscle and lies relatively deep at about 4 cm from skin surface
- MR is next best means of imaging brachial plexus, particularly in post-traumatic setting

BRACHIAL PLEXUS

GRAPHICS

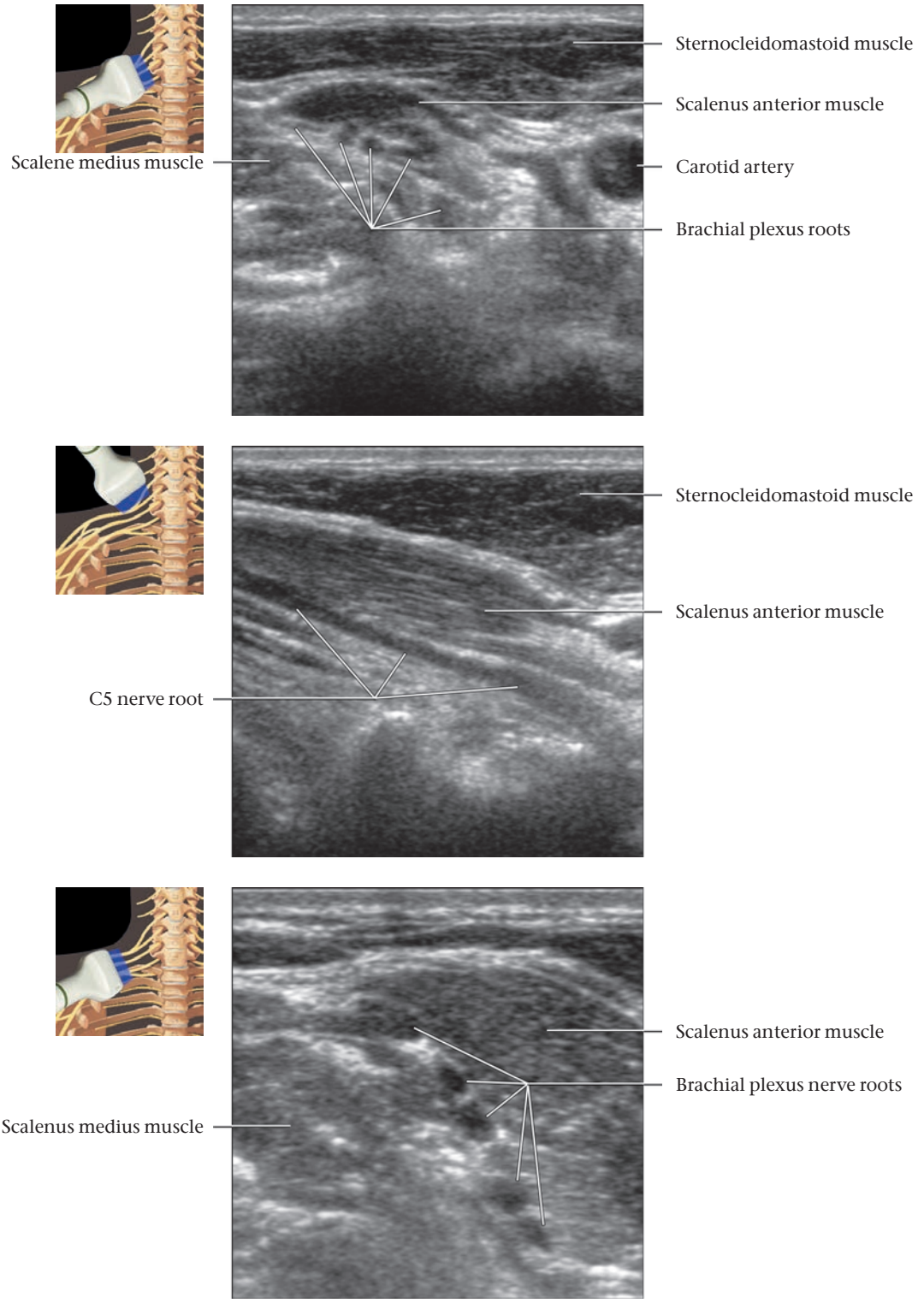




(Top) *Coronal graphic of the cervical spine and supraclavicular brachial plexus demonstrates the cervical ventral primary rami combining to form the brachial plexus. The C1-7 roots exit above the same numbered pedicle, C8 exits above the T1 pedicle, and more caudal roots exit below their numbered pedicle. The trunks are visualized on ultrasound mainly in the intrascalene area.* ***(Bottom)*** *Coronal graphic of the brachial plexus demonstrates the more distal plexus elements extending into the axilla. The trunks recombine into posterior and anterior divisions that form the cords. The posterior cord forms the radial and axillary nerves. The medial cord forms the ulnar nerve, while the lateral cord forms the musculocutaneous nerve. The median nerve is formed from branches of both the lateral and medial cords.*

BRACHIAL PLEXUS

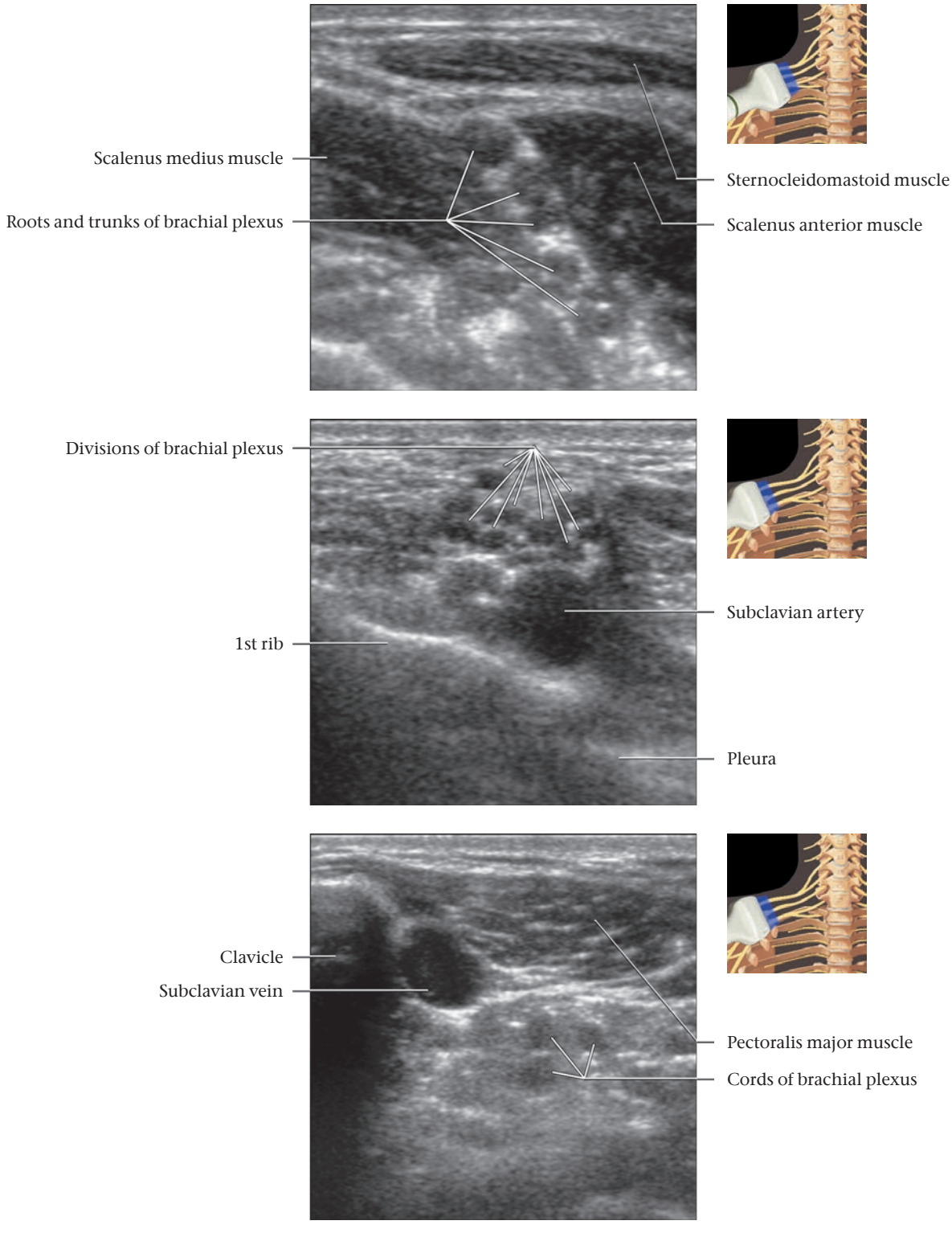
TRANSVERSE AND LONGITUDINAL ULTRASOUND



(Top) *Transverse ultrasound of the anterolateral lower neck shows the hypoechoic roots of the brachial plexus as they exit the neural foramina and move to the intrascalene area.* ***(Middle)*** *Longitudinal ultrasound shows longitudinal section of the hypoechoic C5 nerve root as it emerges from the exit of the foraminal area and descends to the intrascalene area.* ***(Bottom)*** *Transverse ultrasound at entry into the intrascalene area shows 5 hypoechoic roots of the brachial plexus between the scalenus anterior and medius muscles. The hypoechoic roots are clearly seen against the adjacent hyperechoic intermuscular fat.*

BRACHIAL PLEXUS

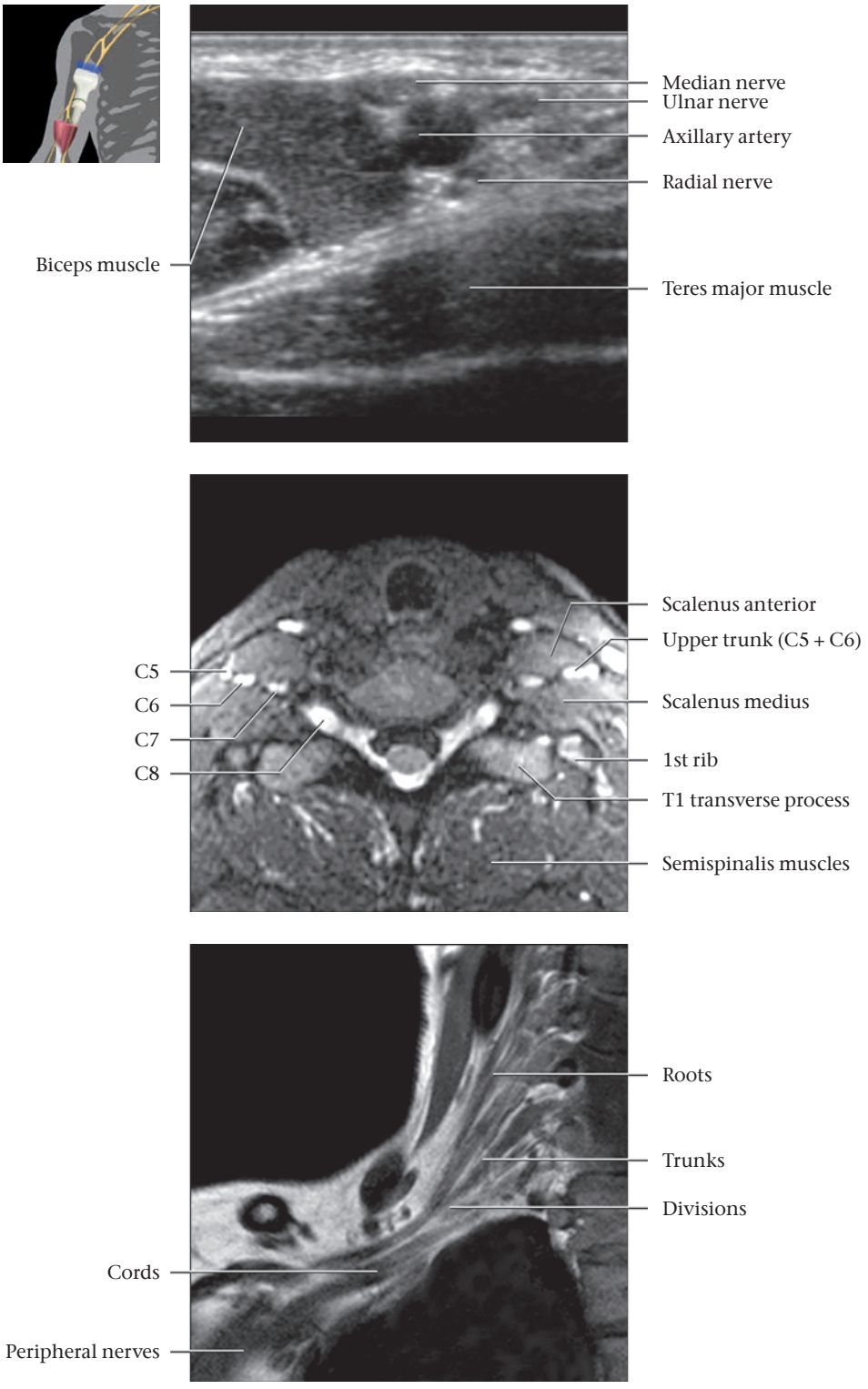
TRANSVERSE ULTRASOUND



(Top) *Transverse ultrasound at the exit from the intrascalene area shows 5 hypoechoic roots and trunks of the brachial plexus between the scalenus anterior and medius muscles. The roots and trunks of the brachial plexus are readily seen between the scalene muscles, but there is considerable variability in their appearance due to the inherent variability in the brachial plexus regarding the formation of the individual trunks, divisions, and cords.* ***(Middle)*** *Transverse ultrasound at supraclavicular area shows hypoechoic divisions of the brachial plexus located dorsocranial to the subclavian artery akin to a "cluster of grapes." In a small percentage of subjects, some of the divisions may lie caudal to the subclavian artery.* ***(Bottom)*** *Transverse ultrasound at infraclavicular area shows hypoechoic cords of the brachial plexus located dorsocaudal to the subclavian artery. More medially, the cords are covered by the pectoralis major muscle while more laterally they are covered also by the pectoralis minor muscle.*

BRACHIAL PLEXUS

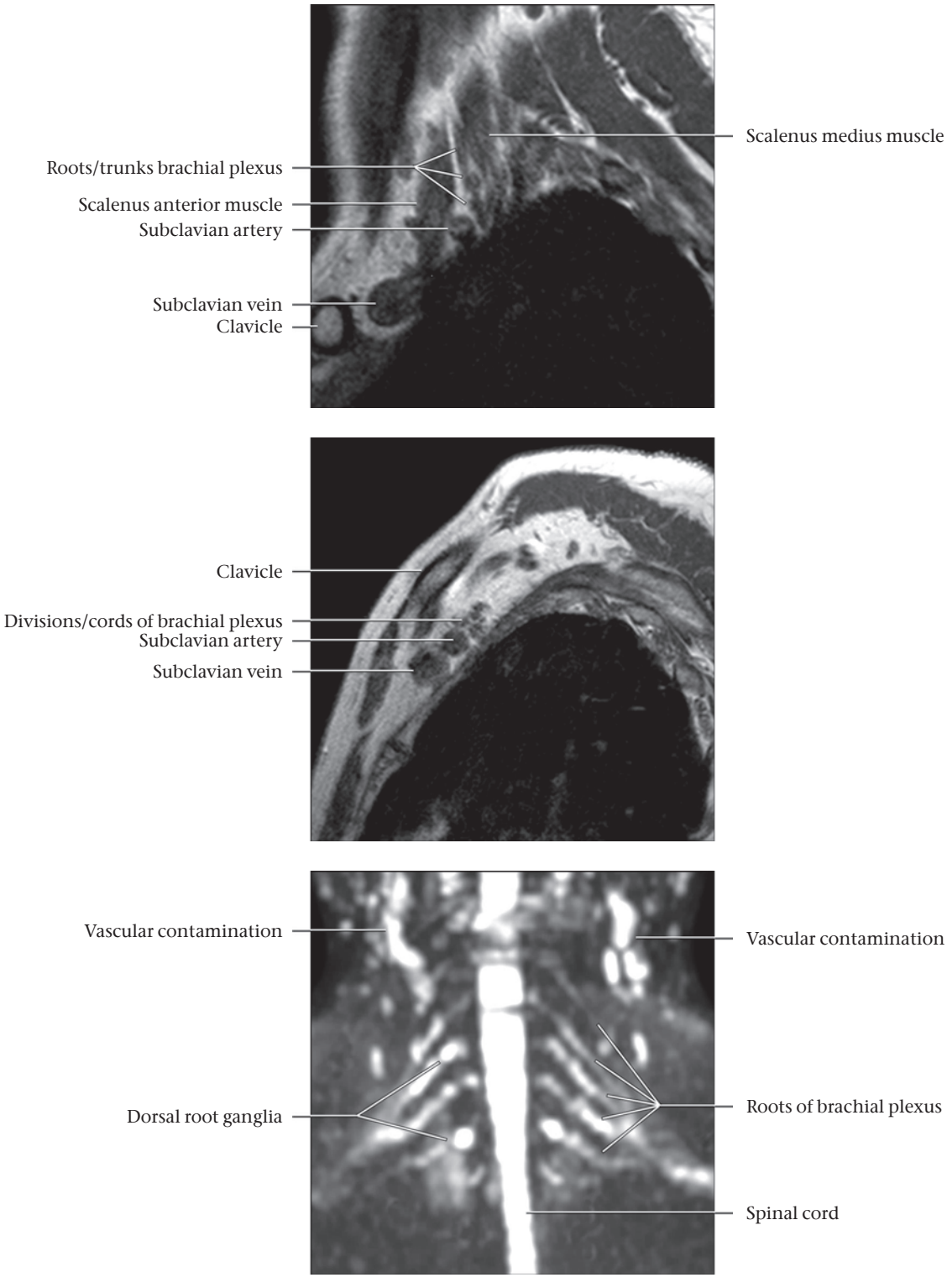
ULTRASOUND AND MR



(Top) *Transverse ultrasound at the upper axillary region shows the axillary artery surrounded by the median, ulnar, and radial nerves. The position of these nerves can vary with regard to the axillary artery, so each nerve should be traced distally to confirm its identity.* ***(Middle)*** *Axial STIR MR at the C7/T1 level depicts the linear alignment of the C5 through C8 ventral primary rami (VPR). C5 and C6 are closely approximated and form the left upper trunk.* ***(Bottom)*** *Oblique coronal T1WI MR with large field of view shows the normal brachial plexus. The divisions and cords run alongside the subclavian artery. The approximate locations of the roots, trunks, divisions, cords, and peripheral nerves are shown.*

BRACHIAL PLEXUS

MR



(Top) *Sagittal T1WI MR shows the hypoechoic roots/trunks of the brachial plexus in the intrascalene area between the scalenus anterior and medius muscles. The scalenus anterior muscle separates the subclavian artery from the subclavian vein.* ***(Middle)*** *Sagittal T1WI MR shows the infraclavicular region (costocervical space) with the hypointense divisions/cords of the brachial plexus located dorsocephalad to the subclavian artery.* ***(Bottom)*** *Coronal reformatted diffuse weighted image shows the normal brachial plexus. The nerve roots can be depicted as individual structures bilaterally. Some of the dorsal root ganglia are also seen. There is signal contamination from vascular structures in the neck.*

RIBS AND INTERCOSTAL SPACE

GENERAL ANATOMY AND FUNCTION

Chest Wall Anatomy

- Skin, subcutaneous fat
- Blood vessels, lymphatics, nerves
- Bone, cartilage
- Muscles
- Endothoracic fascia: Fibroelastic connective tissue between inner aspect of chest wall and parietal pleura

Function

- Musculoskeletal cage: Surrounds cardiorespiratory system; affects respiration by expanding and contracting during ventilation

Surface Landmarks

- Suprasternal (jugular) notch: At superior manubrium of sternum; between sternal ends of clavicles
- Sternal angle: Landmark for internal thoracic anatomy; anterior projection at level of costal cartilage of 2nd rib
- Costal margin: Inferior margins of lowest ribs and costal cartilages

SKELETAL STRUCTURES

Sternum

- Flat, broad bone that forms anterior thoracic wall; 3 parts
  - Manubrium forms superior part of sternum
  - Body articulates with manubrium superiorly, xiphoid process inferiorly, bilateral costal cartilages of 2nd-7th ribs
  - Xiphoid process variable size, shape, ossification; articulates with body of sternum superiorly

Ribs

- 12 pairs, symmetrically arrayed; numbered in accordance with attached vertebral body
- True ribs (1-7) attach to sternum by costal cartilages (synovial joints)
- False ribs (8-10) articulate by costal cartilages with costal cartilage of 7th rib
- Floating ribs (11-12) do not articulate with sternum or rib costal cartilages; short costal cartilages terminate in abdominal wall muscle
- Head articulates with hemifacets of 2 adjacent vertebral bodies; neck is located between head and tubercle of each rib; tubercle articulates with vertebral transverse process
- Body: Longest part of each rib
- Angle: Most posterior part
- Ribs can be broadly categorized as midclavicular, anterior axiliary, midaxillary, posterior axillary, and dorsal sections
- Costal groove on inner surface of inferior border, which accommodates intercostal neurovascular bundle

MUSCLES

Pectoral

- Pectoralis major: Largest muscle in pectoral region; extends from anterior chest wall, sternum, and clavicle to the lateral lip of bicipital groove
  - Adducts, flexes, and medially rotates arm
  - Prone to hypoplasia or aplasia: Sternocostal > clavicle portion > whole muscle
- Pectoralis minor: Deep to pectoralis major; extends from chest wall to coracoid process of scapula
  - Stabilizes scapula
- Sternalis: Anatomical variant (in 5% of cadavers), runs parallel to sternum & connects sternocleidomastoid to rectus abdominus

Intercostal

- External: Contained within 11 intercostal spaces; extends from tubercle of ribs to costochondral junction
- Internal: Middle layer; occupies 11 intercostal spaces; extends from border of sternum to angle of ribs
- Innermost: Forms inner layer of chest wall muscles with subcostales and transversus thoracis muscles

Serratus Anterior

- Thin muscular sheet; overlies lateral thoracic cage and intercostal muscles; arises from upper 8 ribs; wraps around rib cage; inserts along medial anterior surface of scapula

VESSELS AND NERVES

Arteries

- Internal thoracic (internal mammary): Branch of subclavian artery; descends posterior to first 6 costal cartilages; supplies upper anterior chest wall
  - Supplies anterior intercostal arteries to first 6 intercostal spaces

Veins

- Azygos vein receives drainage from posterior intercostal veins, hemiazygos and accessory hemiazygos veins

Nerves

- Anterior rami of thoracic spinal nerves (T1-T11) form intercostal nerves
- Intercostal nerves run in costal groove between internal and innermost intercostal muscles
- T1-T2 supply upper limb, T3-T6 supply chest wall, T7-T11 supply chest and abdominal wall, T12 supplies abdomen and groin

IMAGING

Radiography

- Limited capability for chest wall abnormalities; may detect congenital deformities and other bony abnormality
  - Poor sensitivity to rib fracture detection
  - Even localized rib views will reveal < 20% of rib fractures

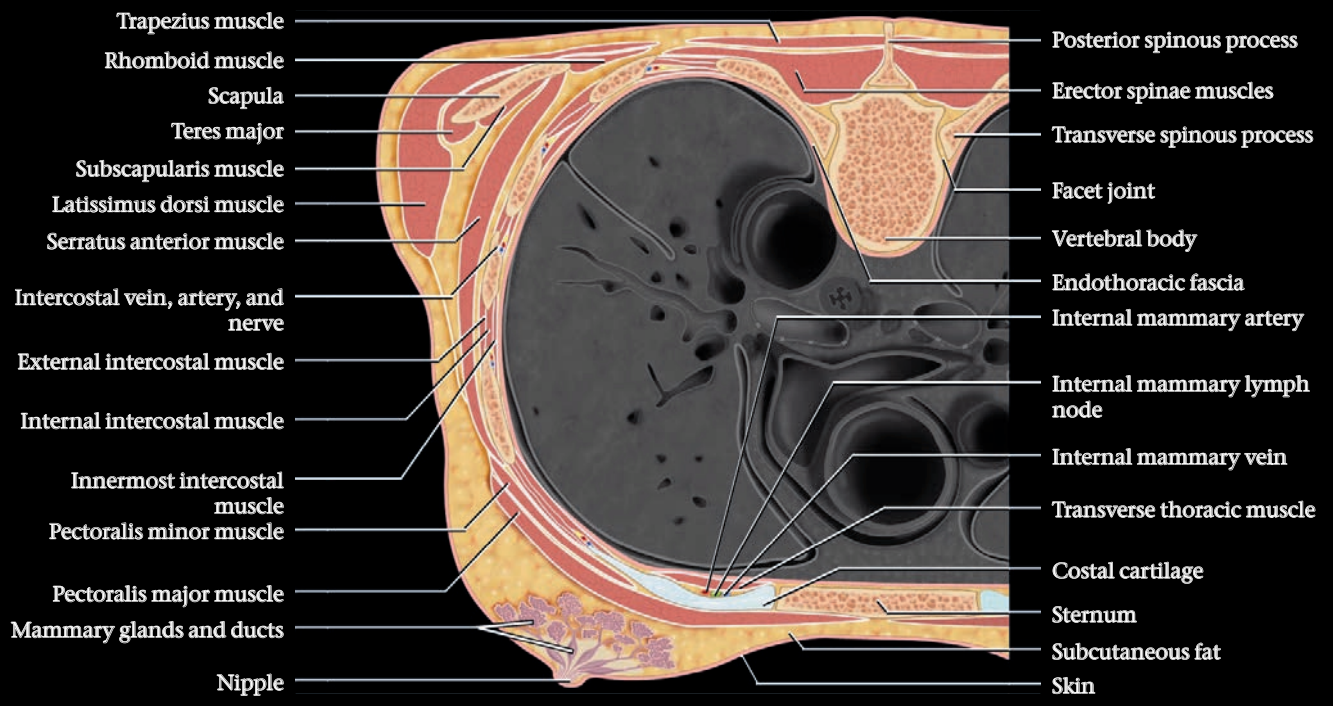
Ultrasound

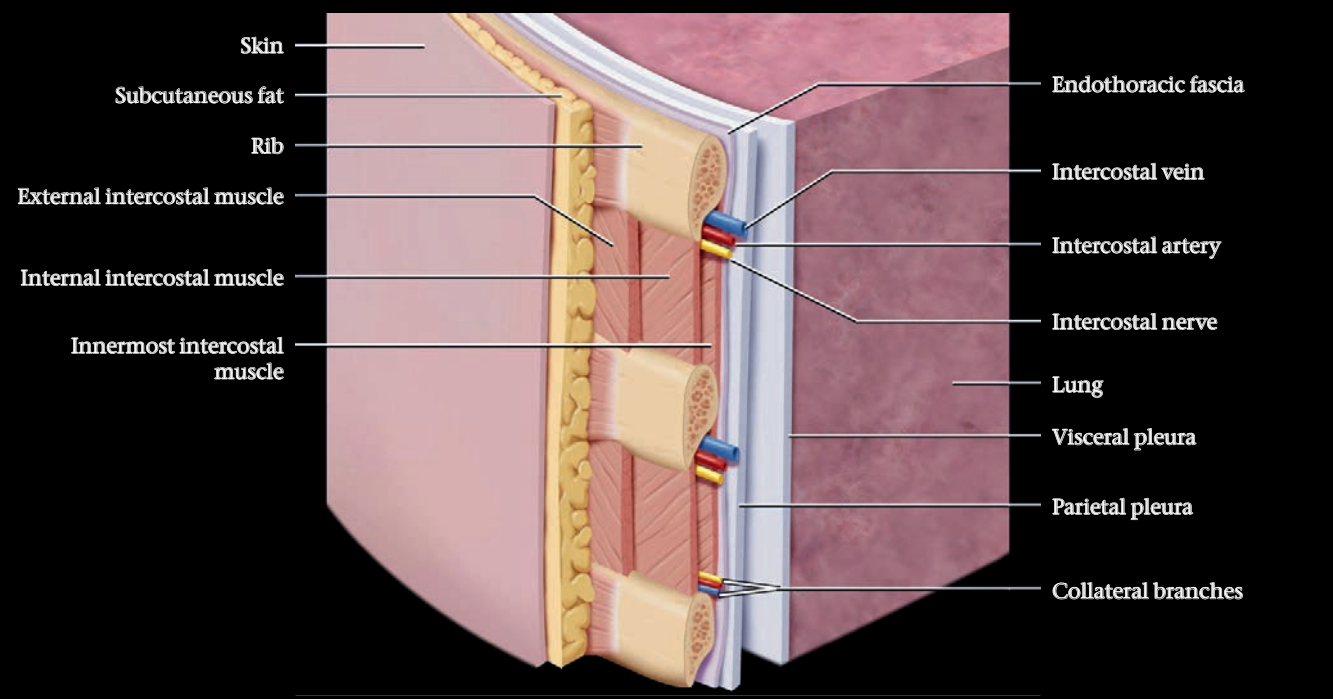
- Allows detailed examination of intercostal spaces, ribs, and costal cartilages
- Intercostal muscles are seen as hypoechoic structures
- Intercostal membrane is seen as hyperechoic layer
  - Intercostal structures are often thin, making it difficult to separate them into distinct layers
- Only anterior cortex of ribs evaluated
- Costal cartilage and costochondral junction clearly seen

Computed Tomography

- Multidetector CT with multiplanar reformations provides excellent visualization of chest wall lesions

GRAPHICS, RIBS AND INTERCOSTAL SPACES

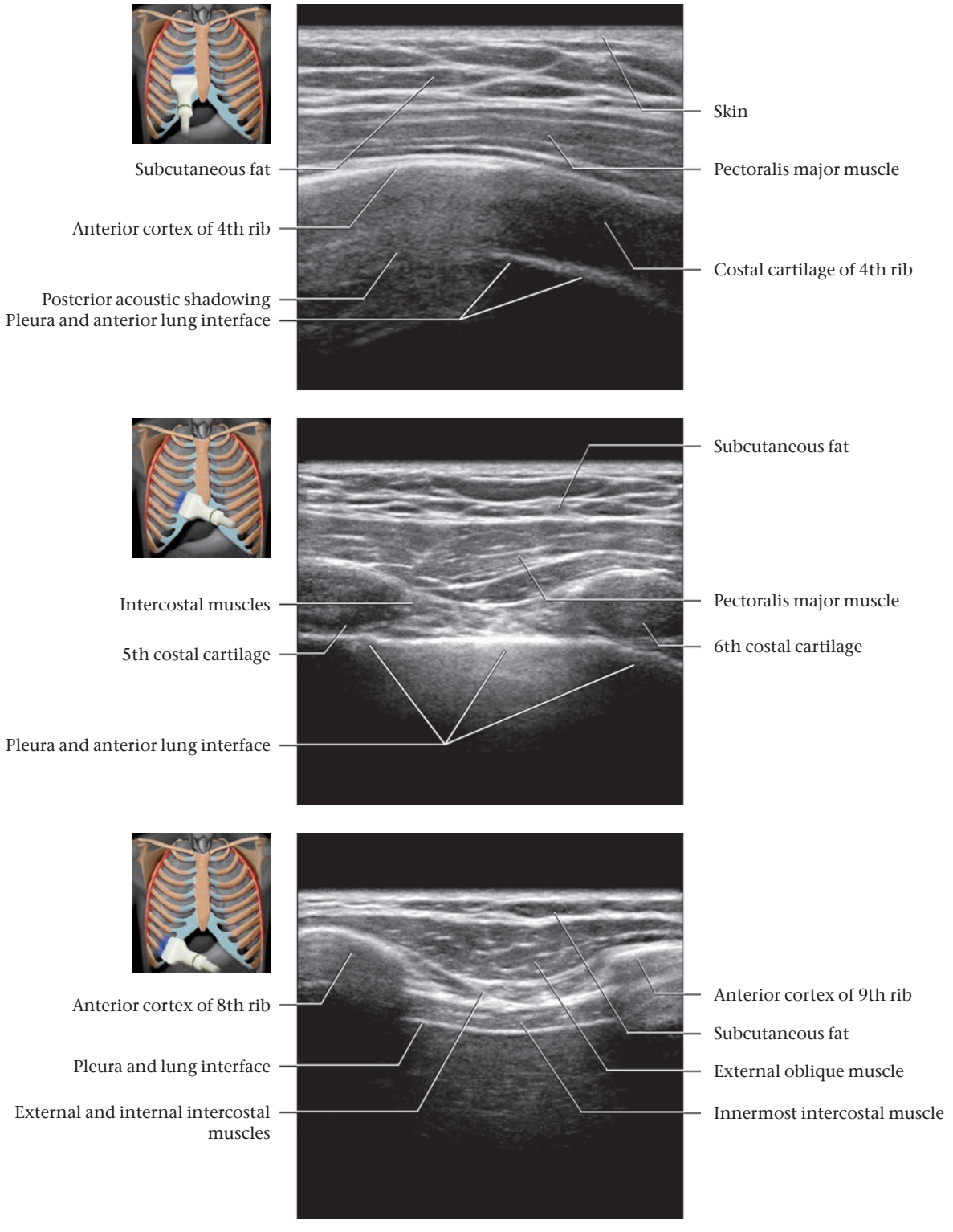




*(**Top**) Graphic depicts the chest wall layers as visualized in the axial plane including skin, subcutaneous fat, blood vessels, lymphatics, and musculoskeletal structures. The innermost layer, the endothoracic fascia, is a fibroelastic connective tissue layer between the inner aspect of the chest wall and the pleura. (**Bottom**) Graphic demonstrates details of the intercostal region, showing 3 layers of intercostal muscles (external, internal, and innermost) between the ribs. The costal groove along the inferomedial aspect of each rib accommodates the intercostal neurovascular bundle (vein, artery, and nerve). Small collateral branches of the major intercostal vessels and nerves may be present above the body of the subjacent rib. The endothoracic fascia forms a connective tissue layer between the inner aspect of the chest wall and the costal parietal pleura.*

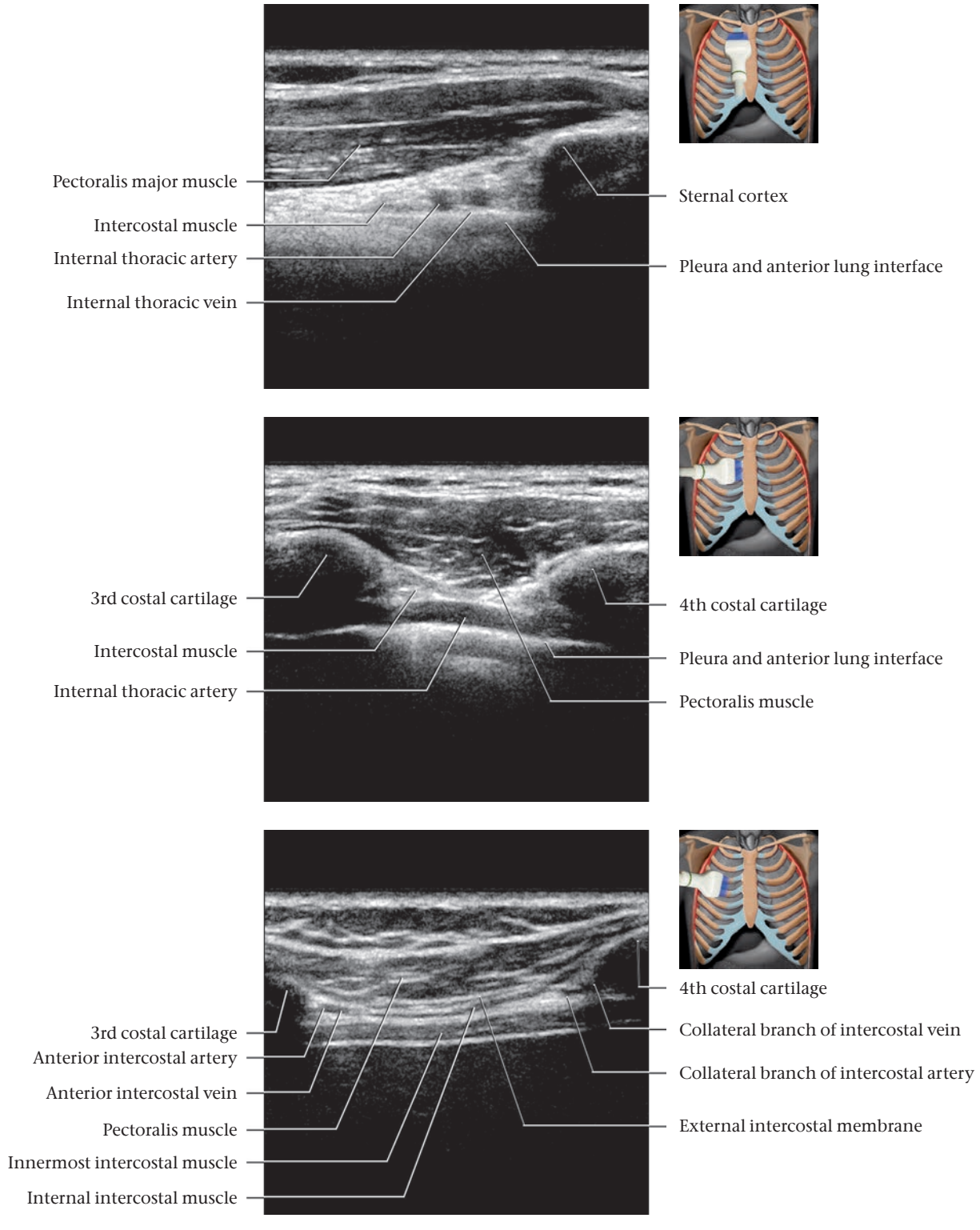
RIBS AND INTERCOSTAL SPACE

RIBS AND INTERCOSTAL SPACES



(Top) *Transverse view shows the costochondral junction of the 4th rib. The costal cartilage appears homogeneously hypoechoic and does not produce significant posterior acoustic shadowing, thus allowing the underlying pleural surface to be seen. The cortex of 4th rib casts a strong posterior shadow, obscuring the underlying pleura.* ***(Middle)*** *Oblique sagittal view shows intercostal space between the costal cartilages in the anterior chest wall. The costal cartilages are well defined and oval shaped on cross section. Intercostal muscles between the costal cartilages and overlying pectoralis muscle can be clearly visualized.* ***(Bottom)*** *More laterally, oblique sagittal view shows intercostal spaces between ribs. Areas behind the ribs are obscured by acoustic shadowing. The intercostal muscles laterally are better differentiated compared to those located more anteriorly.*

RIBS AND INTERCOSTAL SPACES



(Top) *Transverse view shows the anterior intercostal space just lateral to the sternum. The internal thoracic artery and vein next to the sternum are well visualized with this approach, as are the overlying pectoralis muscle and underlying pleura.* ***(Middle)*** *Sagittal view of the anterior intercostal space shows the internal thoracic artery. The long axis of the internal thoracic artery can be well delineated by scanning along the lateral margin of the sternum.* ***(Bottom)*** *Sagittal view shows anterior intercostal space and the anterior intercostal vessels. The anterior intercostal artery and anterior intercostal vein are identified just inferior to the rib above. Smaller collateral branches of intercostal artery and vein can be identified just superior to the rib above. At the anterior intercostal space, the external intercostal muscle is seen as a thin membrane.*

ABDOMINAL WALL AND PARASPINAL STRUCTURES

TERMINOLOGY

Definitions

- Abdomen: Region between diaphragm and pelvis

GROSS ANATOMY

Anatomic Boundaries

- Anterior abdominal wall is bounded superiorly by xiphoid process and costal cartilages of 7th-10th ribs
- Anterior wall is bounded inferiorly by iliac crest, iliac spine, inguinal ligament, and pubis
- Inguinal ligament is inferior edge of aponeurosis of external oblique muscle

Muscles of Anterior Abdominal Wall

- Consist of 3 flat muscles (external oblique, internal oblique, and transverse abdominal), and 1 strap-like muscle (rectus)
- Combination of muscles and aponeuroses (sheet-like tendons) act as a corset to confine and protect abdominal viscera
- Linea alba is a fibrous raphe stretching from xiphoid to pubis
  - Forms central anterior attachment for abdominal wall muscles
  - Formed by interlacing fibers of aponeuroses of oblique and transverse abdominal muscles
  - Rectus sheath is also formed by these aponeuroses as they surround rectus muscle
- External oblique muscle
  - Largest and most superficial of 3 flat abdominal muscles
  - Origin: External surfaces of ribs 5-12
  - Insertion: Linea alba, iliac crest, pubis via a broad aponeurosis
- Internal oblique muscle
  - Middle of 3 flat abdominal muscles
  - Runs at right angles to external oblique
  - Origin: Posterior layer of thoracolumbar fascia, iliac crest, and inguinal ligament
  - Insertion: Ribs 10-12 posteriorly, linea alba via a broad aponeurosis, pubis
- Transverse abdominal muscle
  - Innermost of 3 flat abdominal muscles
  - Origin: Lowest 6 costal cartilages, thoracolumbar fascia, iliac crest, inguinal ligament
  - Insertion: Linea alba via broad aponeurosis, pubis
- Rectus abdominis muscle
  - Origin: Pubic symphysis and pubic crest
  - Insertion: Xiphoid process and costal cartilages 5-7
  - Rectus sheath: Strong fibrous compartment that envelops each rectus muscle
    - Contains superior and inferior epigastric vessels
  - 3 tendinous intersections divide rectus sheath into distinct muscle bellies
    - This gives rise to '6-pack' appearance of well-developed rectus abdominus musculature
  - Arcuate line lies about midway between umbilicus and pubic crest
    - Above arcuate line, internal oblique aponeurosis splits to enclose rectus muscle
    - Below arcuate line, internal oblique passes wholly in front of rectus muscle so that rectus muscle lies directly on transversalis fascia
- Actions of anterior abdominal wall muscles
  - Support and protect abdominal viscera
  - Help flex and twist trunk, maintain posture
  - Increase intraabdominal pressure for defecation, micturition, and childbirth
  - Stabilize pelvis during walking, sitting up
- Transversalis fascia
  - Lies deep to abdominal wall muscles and lines entire abdominal wall
  - Separated from parietal peritoneum by layer of extraperitoneal fat

Muscles of Posterior Abdominal Wall

- Consist of psoas (major and minor), iliacus, and quadratus lumborum
- Psoas: Long, thick, fusiform muscle lying lateral to vertebral column
  - Origin: Transverse processes and bodies of vertebrae T12-L5
  - Insertion: Lesser trochanter of femur (passing behind inguinal ligament)
  - Action: Flexes thigh at hip joint; bends vertebral column laterally
- Iliacus: Large triangular sheet of muscle lying along lateral side of psoas
  - Origin: Superior part of iliac fossa
  - Insertion: Lesser trochanter of femur (after joining with psoas tendon)
  - Action: "Iliopsoas muscle" flexes thigh
- Quadratus lumborum: Thick sheet of muscle lying adjacent to transverse processes of lumbar vertebrae
  - Invested by lumbodorsal fascia
  - Origin: Iliac crest and transverse processes of lumbar vertebrae
  - Insertion: 12th rib
  - Actions: Stabilizes position of thorax and pelvis during respiration, walking
    - Bends trunk to side

Paraspinal Muscles

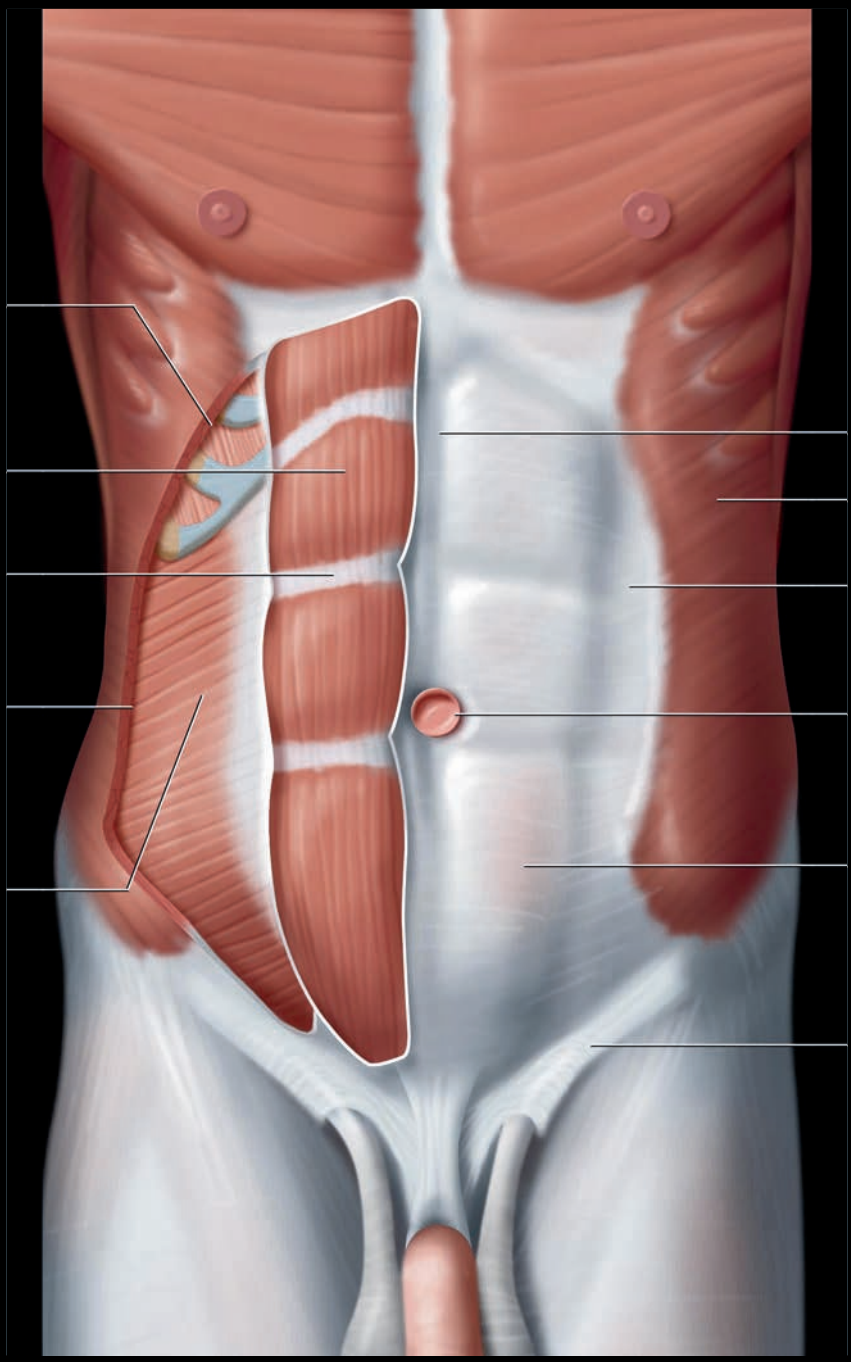
- Also called erector spinae muscles
  - Invested by lumbodorsal fascia
- Composed of 3 columns
  - Iliocostalis: Lateral
  - Longissimus: Intermediate
  - Spinalis: Medial
- Origins: Sacrum, ilium, and spines of lumbar and 11th-12th thoracic vertebrae
- Insertions: Ribs and vertebrae with additional muscle slips joining columns at successively higher levels
- Action: Extends vertebral column

ANATOMY IMAGING ISSUES

Imaging Recommendations

- High-frequency (7-10 MHz) linear transducer for anterior abdominal wall and paraspinal muscles
  - 3-5 MHz for posterior abdominal wall muscles
- Patient may be asked to perform Valsalva maneuver to increase abdominal pressure and exaggerate abdominal wall hernia for better visualization
- Comparison with contralateral side to check for symmetry

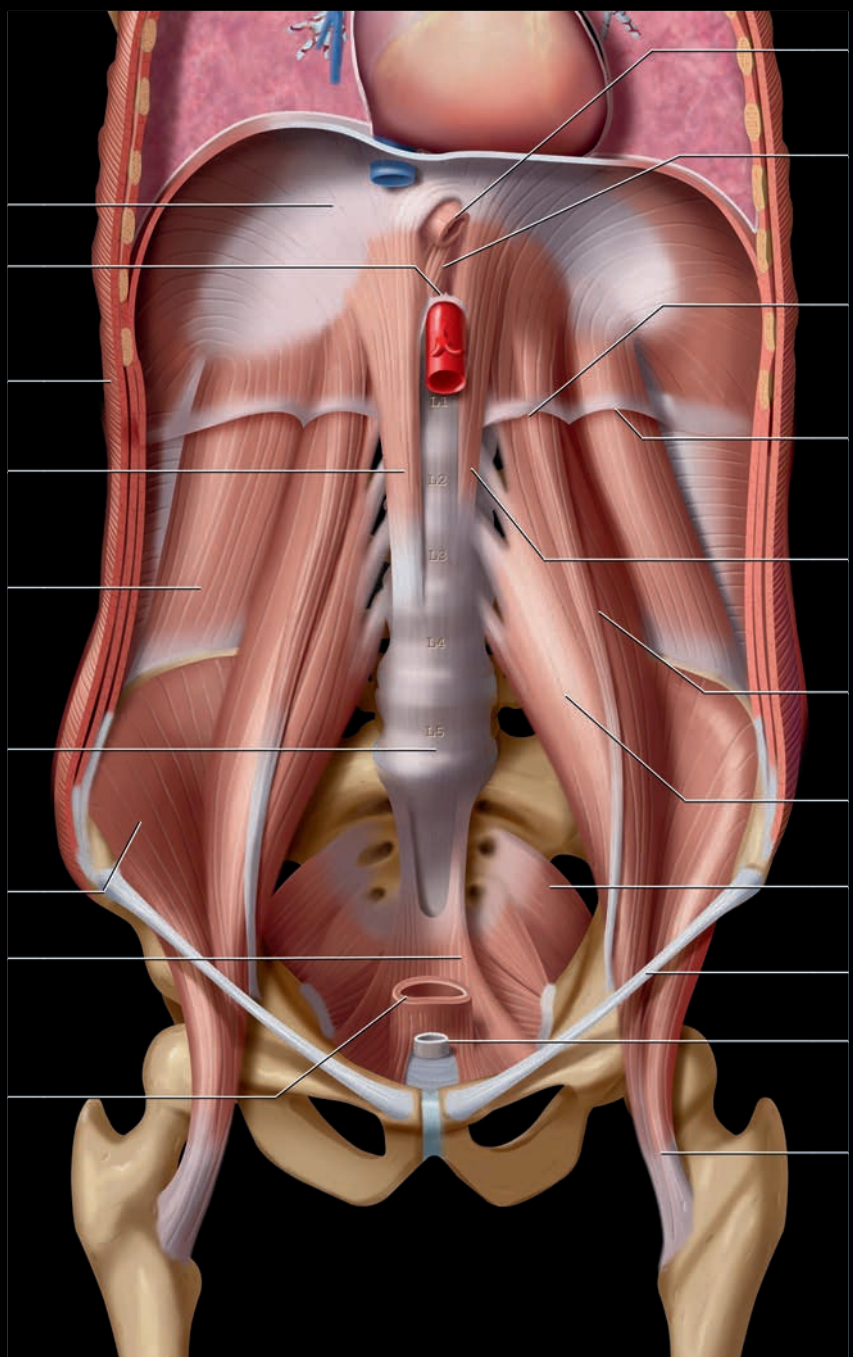
ANTERIOR ABDOMINAL WALL



Graphic shows the aponeuroses of the internal and external oblique and transverse abdominal muscles are 2-layered and interweave with each other, covering the rectus muscle and constituting the rectus sheath and linea alba. About midway between the umbilicus and symphysis, at the arcuate line, the posterior rectus sheath ends. The transversalis fascia is the only structure between the rectus muscle and parietal peritoneum below the arcuate line. The arcuate line is also the location where the inferior epigastric artery enters the rectus sheath.

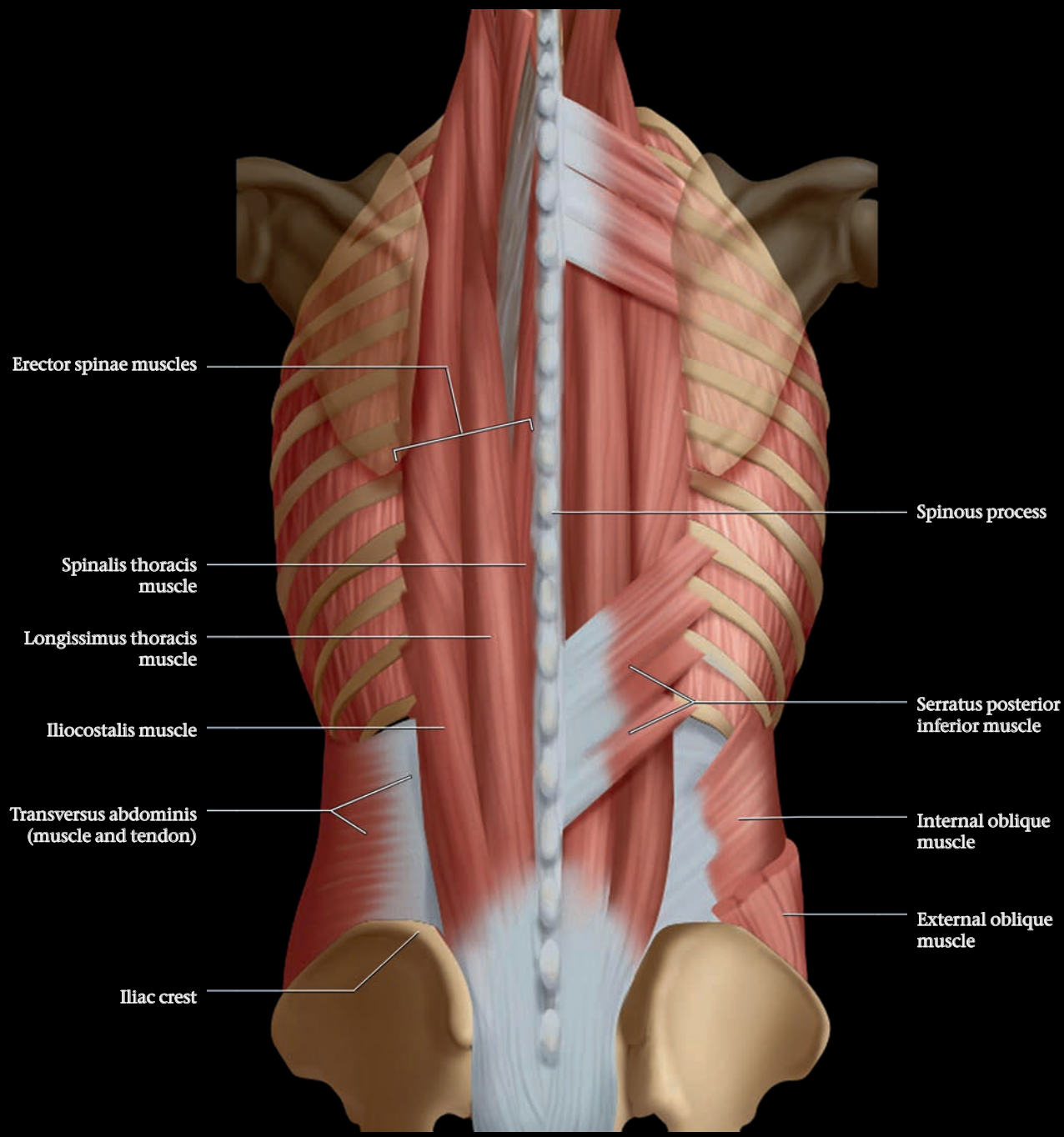
ABDOMINAL WALL AND PARASPINAL STRUCTURES

POSTERIOR ABDOMINAL WALL



Graphic shows the lumbar vertebrae are covered and attached by the anterior longitudinal ligament, and the diaphragmatic crura are closely attached to it, as are the origins of the psoas muscles which also arise from the transverse processes. The iliacus muscle arises from the iliac fossa of the pelvis and inserts into the tendon of the psoas major, constituting the iliopsoas tendon, which inserts into the lesser trochanter. The quadratus lumborum arises from the iliac crest and inserts into the 12th rib and transverse processes of the lumbar vertebrae. Diaphragmatic and transverse abdominal fibers interlace. The psoas and quadratus lumborum pass behind the diaphragm under the medial and lateral arcuate ligaments.

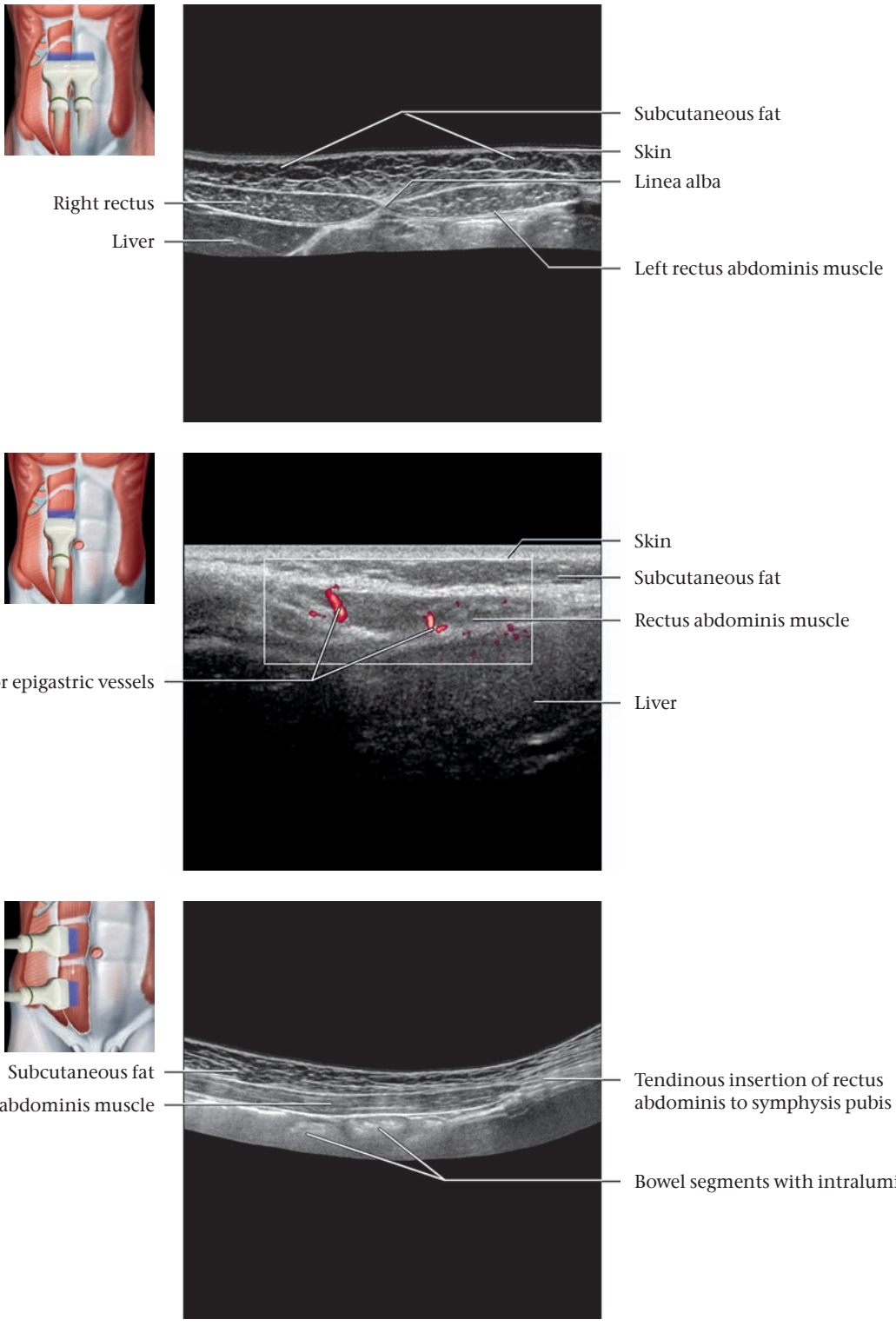
MUSCLES OF BACK IN SITU



Graphic shows the paraspinal muscles and muscles of the back. The latissimus dorsi muscles are not included. The erector spinae have thick tendinous origins from the sacral and iliac crests and the lumbar and 11th-12th thoracic spinous processes. Superiorly, the muscle becomes fleshy and subdivides in the upper lumbar region to become the iliocostalis, longissimus, and spinalis muscles (from lateral to medial), tapering as they insert into the vertebrae and ribs. The erector muscles flank the spinous processes and span the length of the posterior thorax and abdomen. They are responsible for extension of the vertebral column.

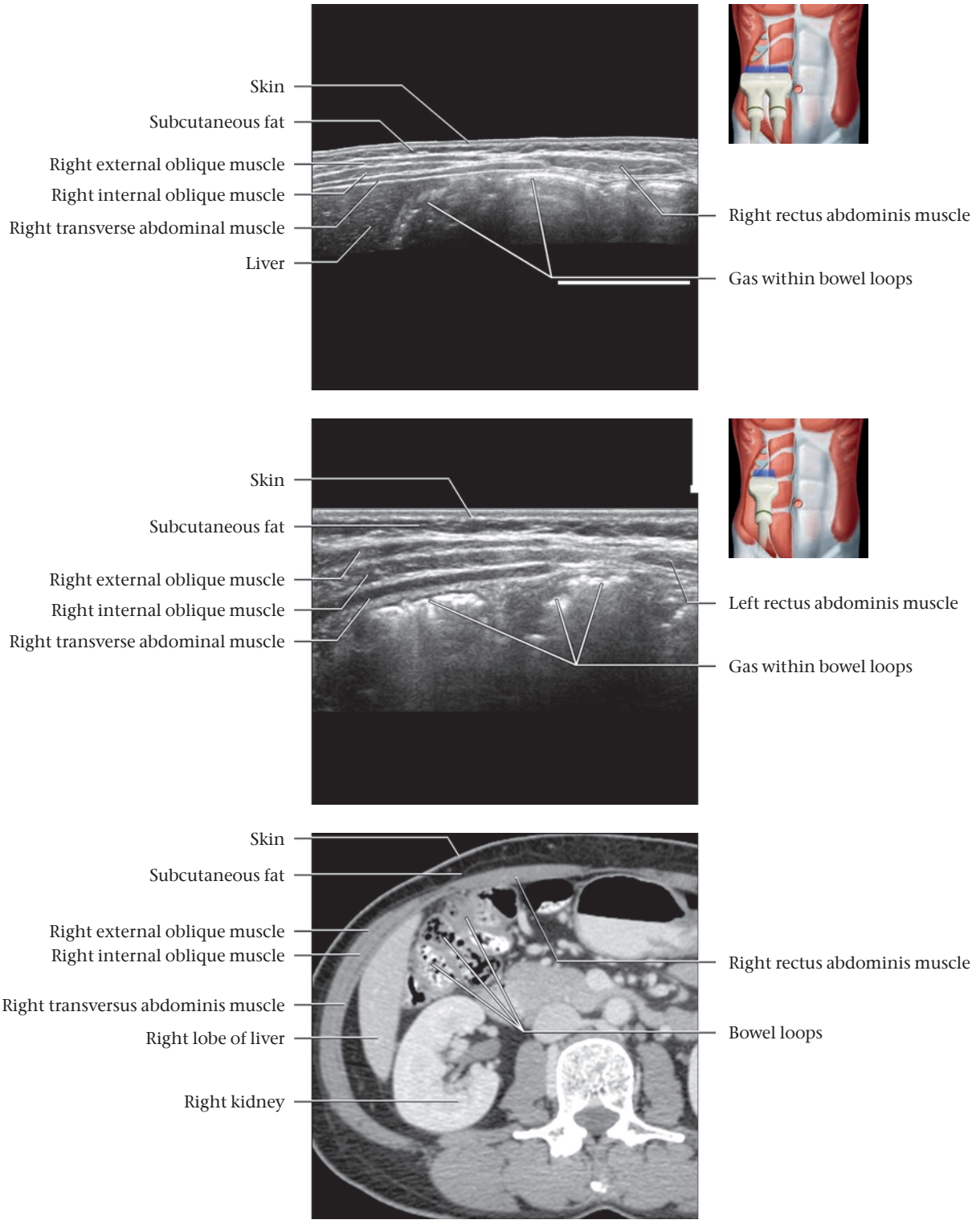
ABDOMINAL WALL AND PARASPINAL STRUCTURES

ANTERIOR ABDOMINAL WALL



(Top) *Transverse extended field of view grayscale ultrasound of the midline anterior abdominal wall shows the paired rectus abdominis muscles separated by the linea alba. The rectus abdominis muscles are comparable in echogenicity and thickness. The surrounding rectus sheath is seen as a fine, thin, echogenic structure around the muscles.* ***(Middle)*** *Transverse color Doppler ultrasound of a rectus abdominis muscle shows arteries within the muscle. At the upper abdomen, these are branches of the superior epigastric artery, and at the lower abdomen comprise branches of the inferior epigastric arteries. These anastomose at the umbilicus.* ***(Bottom)*** *Longitudinal extended field of view (EFOV) grayscale ultrasound shows the distal rectus abdominis muscle and its tendinous insertion into the symphysis pubis. Note how the rectus abdominis muscle tapers distally.*

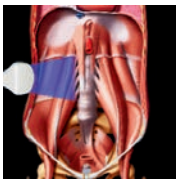
ANTEROLATERAL ABDOMINAL WALL

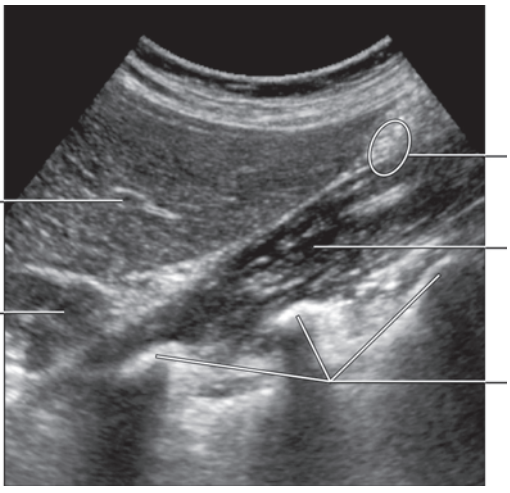


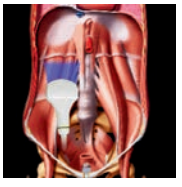
(Top) *Transverse extended field of view grayscale ultrasound shows the relationship of the medially located rectus abdominis and the laterally located oblique and transverse abdominal muscles. Medially, the external and internal oblique and transversus abdominal muscles form aponeuroses that compose the rectus sheath.* ***(Middle)*** *Transverse grayscale ultrasound at the right anterolateral abdominal wall shows the relationship of the lateral abdominal wall muscles in better detail. Note the oblique and transverse abdominal muscles taper medially as they become aponeuroses.* ***(Bottom)*** *Correlative axial contrast-enhanced CT illustrates the muscles of the abdominal wall. The rectus abdominis muscle in the anterior abdominal wall and the oblique and transverse abdominal muscles in the anterolateral abdominal wall and their aponeuroses are shown.*

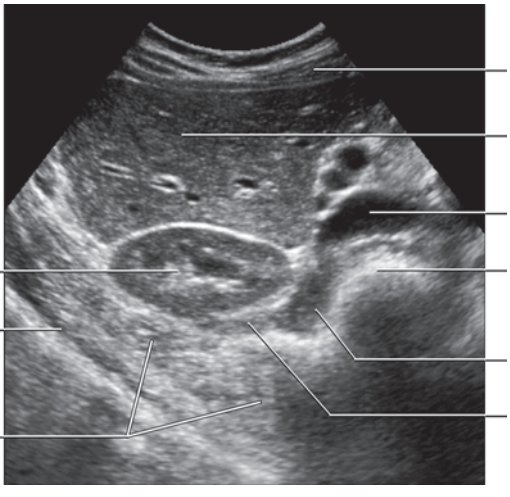
ABDOMINAL WALL AND PARASPINAL STRUCTURES

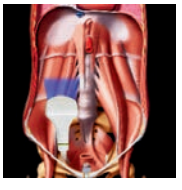
POSTERIOR ABDOMINAL WALL

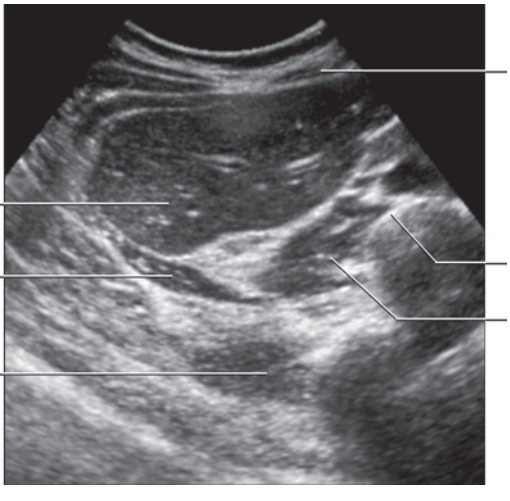






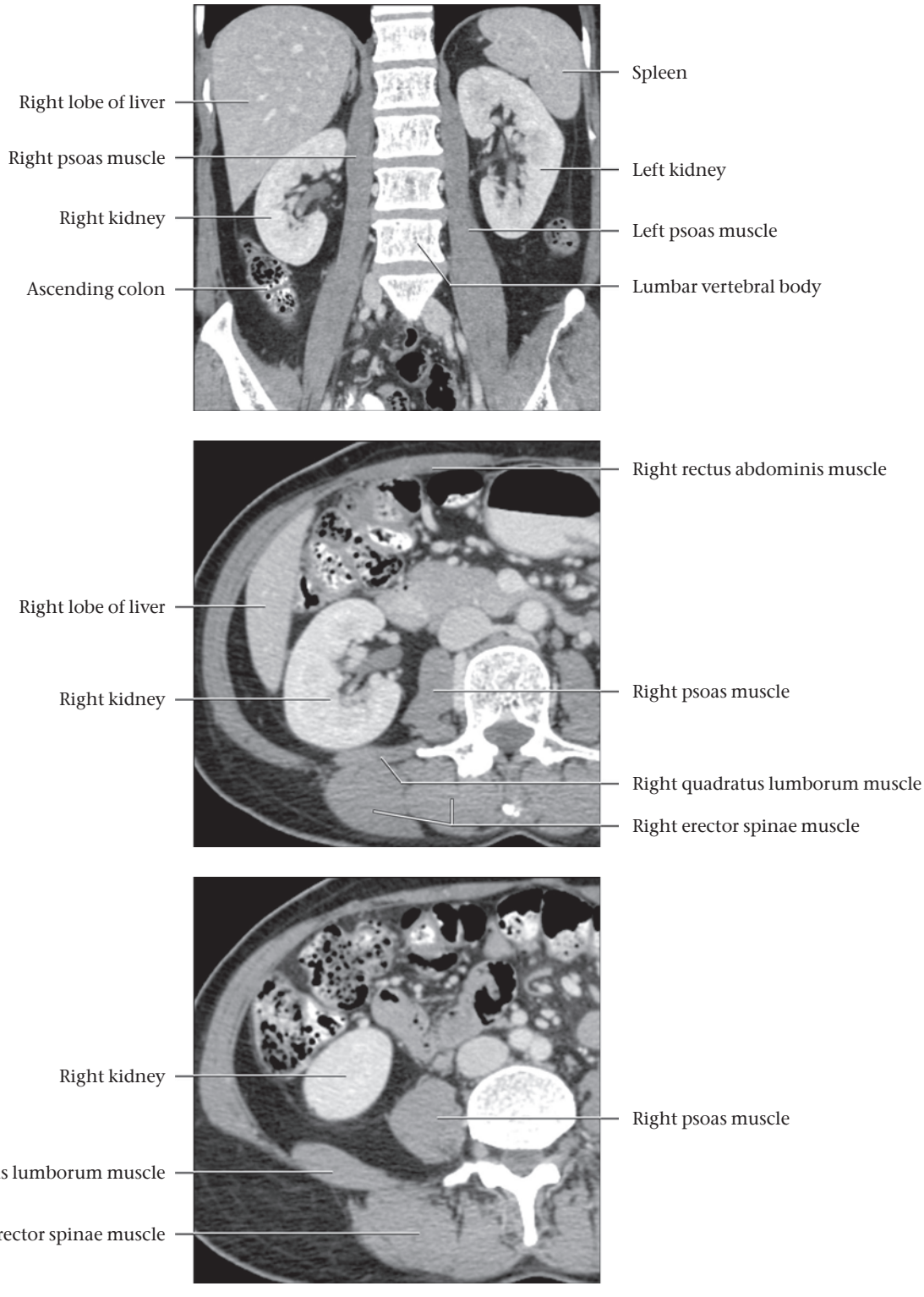






(Top) *Coronal oblique grayscale ultrasound using the liver and right kidney as acoustic windows shows the right psoas muscle that originates from the lumbar spine and inserts into the proximal femur.* ***(Middle)*** *Transverse grayscale ultrasound shows the right upper abdomen using the liver and kidney as acoustic windows. The kidney is identified lateral to the psoas and anterior to the quadratus lumborum. The psoas is identified along the paravertebral region in its entire abdominal course. The quadratus lumborum originates from the iliolumbar ligament and iliac crest to insert into the last rib and lumbar transverse processes. It is easily identified as the muscle on which the kidney rests.* ***(Bottom)*** *Transverse grayscale ultrasound shows the right upper abdomen. Continuing the scan inferiorly, the relationship of the posterior abdominal wall musculature would be maintained.*

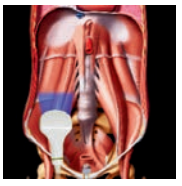
POSTERIOR ABDOMINAL WALL, CT CORRELATION

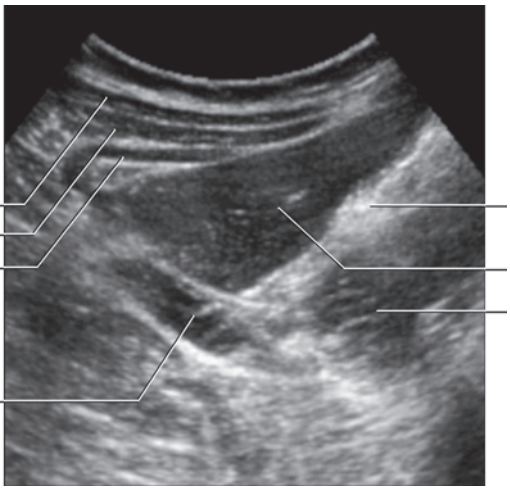


(Top) *Correlative coronal CECT shows the paralumbar location of the psoas muscles and their medial location relative to the kidneys. The psoas muscles originate from the lumbar and 12th thoracic vertebral bodies and their transverse processes, running past the pelvic brim where they course inferolaterally to be joined by the iliacus muscle.* ***(Middle)*** *Correlative axial CECT better illustrates the anatomic relationships of the kidney with the posterior abdominal wall muscles. The kidney is lateral to the psoas muscle and rests upon the quadratus lumborum muscle. The erector spinae muscles are immediately posterior to the quadratus lumborum, and the 2 muscles are invested by lumbodorsal fascia.* ***(Bottom)*** *Correlative axial CECT shows the level of the inferior pole of the right kidney. The psoas muscle and quadratus lumborum muscles, seen in their midsections, are now thicker.*

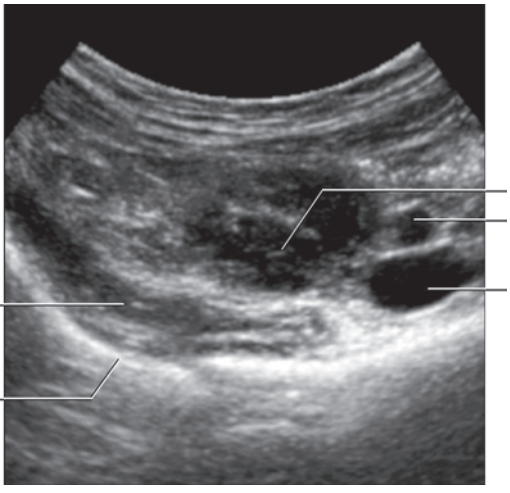
ABDOMINAL WALL AND PARASPINAL STRUCTURES

POSTERIOR ABDOMINAL WALL

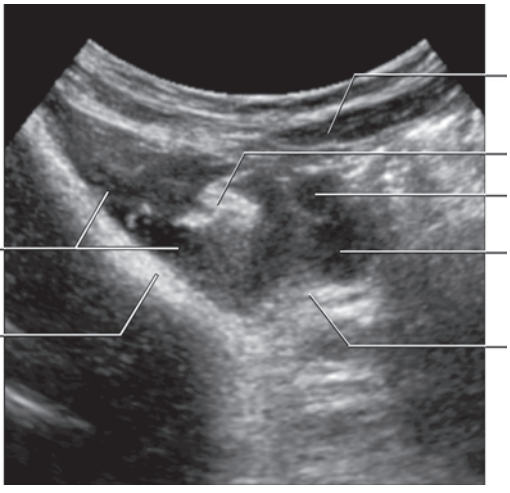






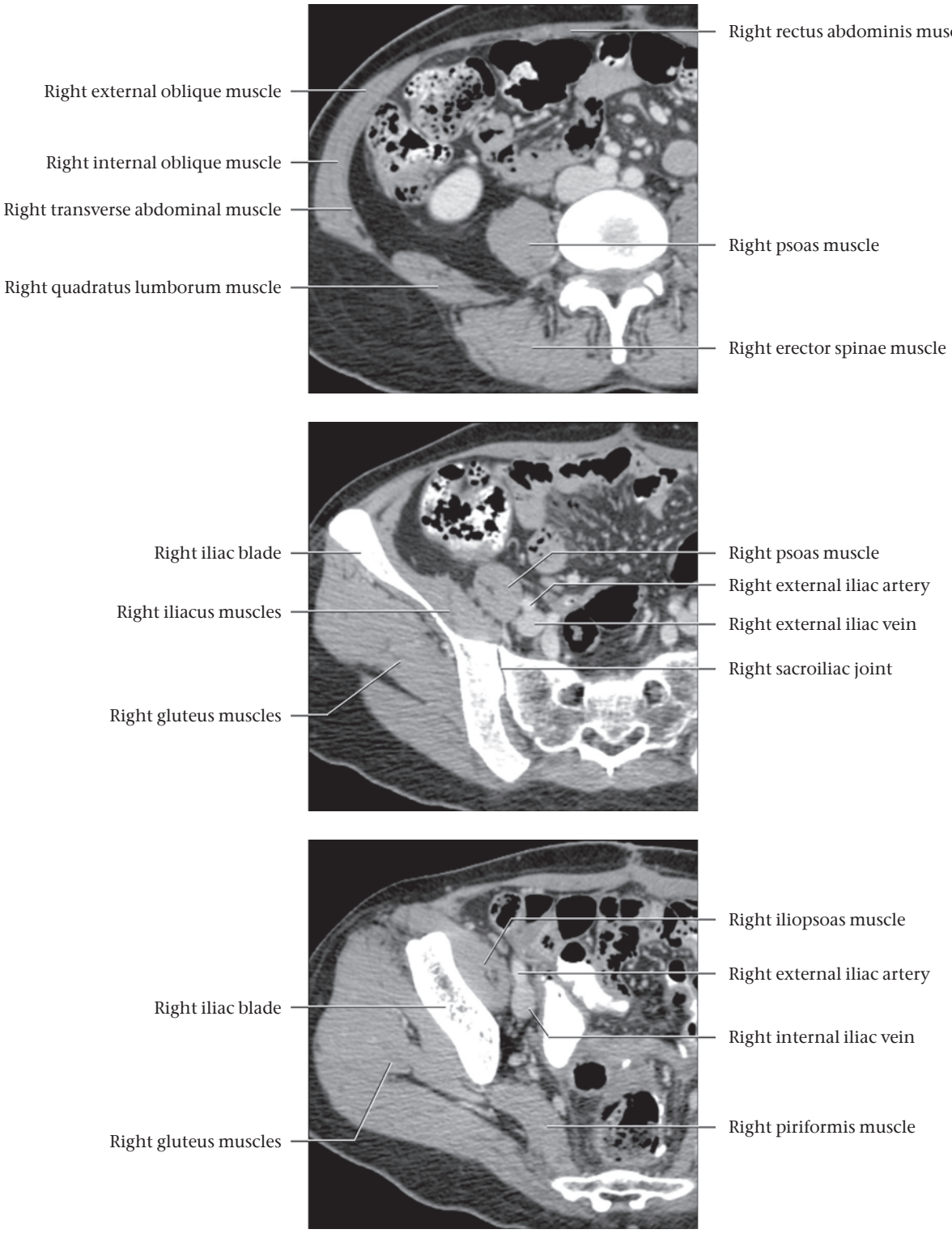






(Top) *Transverse grayscale ultrasound in the lower abdominal region shows the right psoas muscle, composed of the psoas minor resting upon the psoas major muscle. The 2 muscles cannot be separated clearly on ultrasound. Owing to their depth, the paraspinal muscles cannot be demonstrated in detail.* ***(Middle)*** *Transverse grayscale ultrasound of the same patient shows the right lower abdomen. The distal psoas muscle has diminished in size. It rests on the medial portion of the iliacus muscle. The iliacus muscle is a flat muscle that fills the iliac fossa. Both the psoas and iliacus muscles continue inferiorly together.* ***(Bottom)*** *Distally, the fibers from the iliacus muscle converge and insert into the lateral side of the psoas muscle to form the iliopsoas muscle.*

POSTERIOR ABDOMINAL WALL, CT CORRELATION

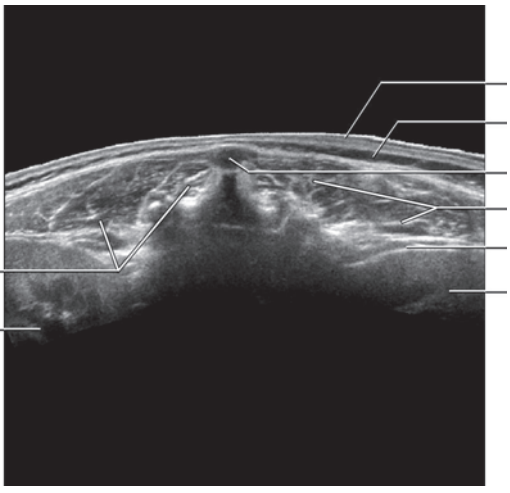


(Top) *Correlative axial CECT shows the level of the inferior pole of the kidney. The quadratus lumborum muscle is more laterally located, and the psoas muscle is directly anterior to the erector spinae muscle.* ***(Middle)*** *Correlative axial CECT shows that the psoas muscle has begun its dorsolateral course and is now anterior to the iliacus muscle. The iliacus muscle is easily identified as a flat muscle filling the iliac fossa, arising from the upper 2/3 of the iliac fossa, inner lip of the iliac crest, anterior sacroiliac and the iliolumbar ligaments, and base of the sacrum.* ***(Bottom)*** *Axial correlative CECT shows the psoas and iliacus muscles have converged and are now indistinguishable. The resultant iliopsoas muscle passes beneath the inguinal ligament and becomes tendinous as it inserts into the lesser trochanter of the femur.*

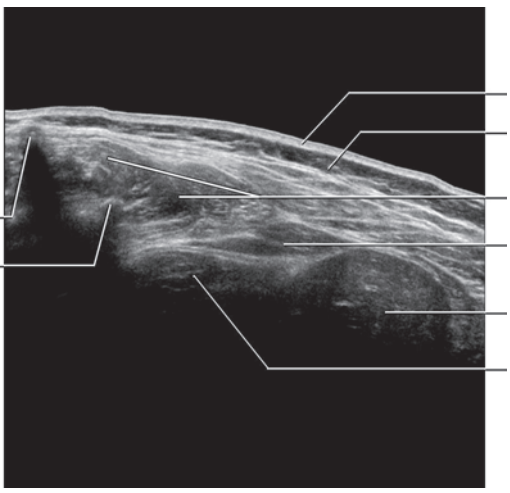
ABDOMINAL WALL AND PARASPINAL STRUCTURES

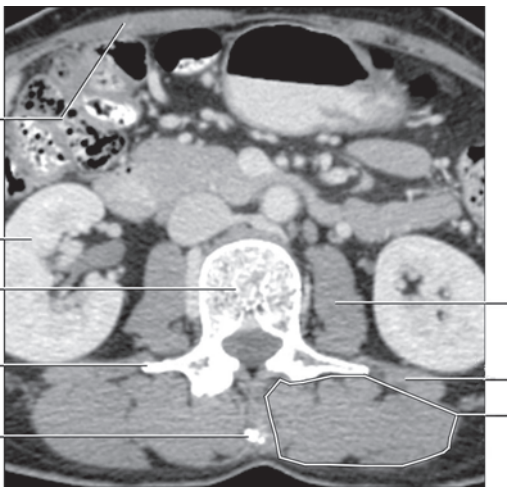
PARASPINAL MUSCLES



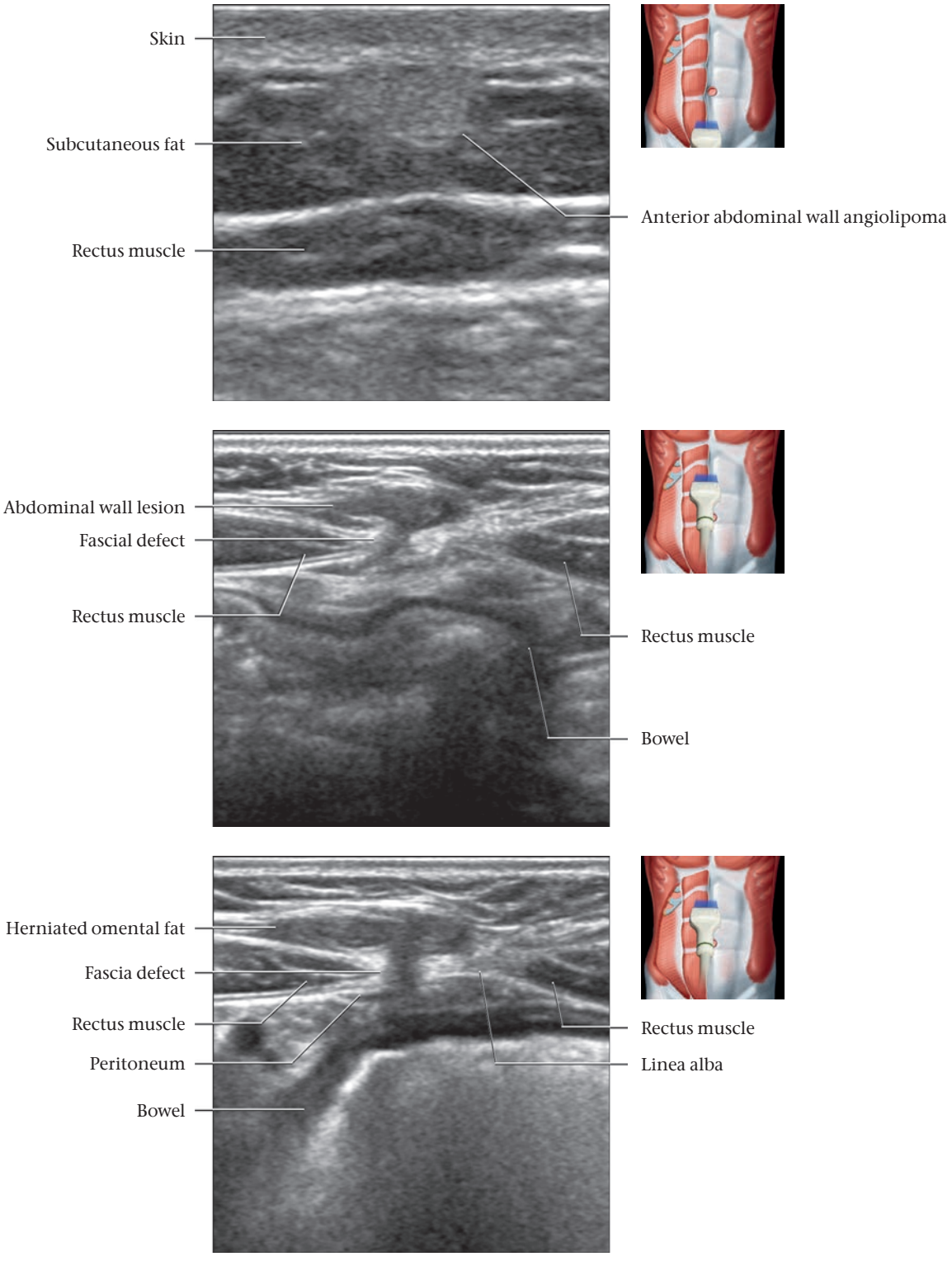








(Top) *Transverse extended field of view grayscale US of the back (with patient prone) shows the erector spinae muscles flanking the spinous process. They are invested by lumbodorsal fascia, which also invests the anteriorly located quadratus lumborum muscle. The kidneys are partially demonstrated.* ***(Middle)*** *Transverse EFOV grayscale US shows the right erector spinae muscle (with patient prone). The 3 columns (iliocostalis, longissimus, and spinalis muscles, from lateral to medial) composing the erector spinae are not clearly separated on ultrasound. They are identified collectively as a thick fleshy muscle lateral to the spinous process.* ***(Bottom)*** *Correlative axial CECT shows the paraspinal muscles at the level of the kidneys. The erector spinae muscles originate from a broad and thick tendon that is attached to the sacrum and iliac crest distally as well as the lumbar and lower 2 thoracic spinous processes more proximally.*



(Top) *Transverse grayscale ultrasound shows a small hyperechoic nodule in the subcutaneous fat of the anterior abdominal wall. Mild intrinsic vascularity on color Doppler imaging was present (not shown). Histology following surgical excision revealed an angiolipoma. No deep extension is present.* ***(Middle)*** *Transverse grayscale ultrasound shows a well-defined hypoechoic mass in the anterior abdominal wall. There is a small fascial defect of the linea alba.* ***(Bottom)*** *Transverse ultrasound of the same patient as the previous image shows widening of the fascial defect and increased herniation of omental fat with Valsalva maneuver. The intraperitoneal communication is much more conspicuous with Valsalva maneuver. Fatty hernias of the linea alba usually occur in the epigastrium and are typically small and painful. The predilection for the epigastrium may be related to extra tension on the linea alba at this location due to pull from the diaphragm.*

GROIN

TERMINOLOGY

Abbreviations
- Artery (a.), anterior superior iliac spine (ASIS), insertion (I), ligament (l.), muscle (m.), origin (O), vein (v.)

Definitions
- Junctional region between thigh and trunk

IMAGING ANATOMY

Overview
- Incorporates lower abdominal wall, inguinal canal, femoral triangle, and femoral adductor muscles

Osseous Anatomy
- Pubic bone
  - **Pubic tubercle**: Small protuberance, lateral border pubic crest
    - Attachment: Inguinal ligament
  - **Superior and inferior rami**: Extend from pubis
  - **Pecten**: Ridge, posterior aspect superior pubis
    - O of pectineus muscle
    - I of conjoint tendon (internal oblique and transverse abdominis)
  - **Pubic crest**: Superior surface, anterior aspect pubic body
    - O of rectus abdominis muscle
    - I of transversus abdominis and external oblique muscles
  - **Pubic symphysis**: Cartilaginous joint between pubic bodies
  - **Superior pubic ligament**: Laterally extends to pubic tubercles

Anterior Abdominal Wall
- Abdominal wall muscles
  - **Rectus abdominis**: Paired midline muscles
    - O: Superior pubic ramus, pubic crest
    - I: Xiphoid process, costal cartilages 5-7
  - **Linea alba**: Aponeurotic junction of rectus femoris, transverse abdominis, and internal & external oblique muscles
  - **External oblique**: Most superficial
    - O: Ribs 5-12
    - I: Pubic crest, anterior iliac crest, linea alba
    - Lower border of aponeurosis contributes to inguinal ligament
  - **Internal oblique**: Between external oblique, transversus abdominis
    - O: Lateral inguinal ligament, iliac crest, thoracolumbar fascia
    - I: Pecten (conjoined tendon), pubic crest, inferior aspect of ribs 10-12, linea alba
    - Origin anterior to deep inguinal ring
    - Insertion lateral to rectus abdominis muscle, posterior and medial to superficial inguinal ring
    - Arches over inguinal canal, forming roof
  - **Transversus abdominis**: Deepest
    - O: Iliac crest, posterior aspect of lateral inguinal ligament, thoracolumbar fascia
    - I: Pubic crest, pecten (conjoined tendon), linea alba
    - Remains posterior to inguinal canal

Inguinal Ligament
- Thickening inferior border of external oblique aponeurosis
- Attachments: ASIS and pubic tubercle
- Separates lower extremity from pelvis
- Fascia lata attaches to inferior border
- **Subinguinal space**: Deep to inguinal ligament
  - Passageway for femoral vessels and nerve, iliopsoas muscle into femoral triangle
  - External iliac vessels become femoral vessels upon entering this space

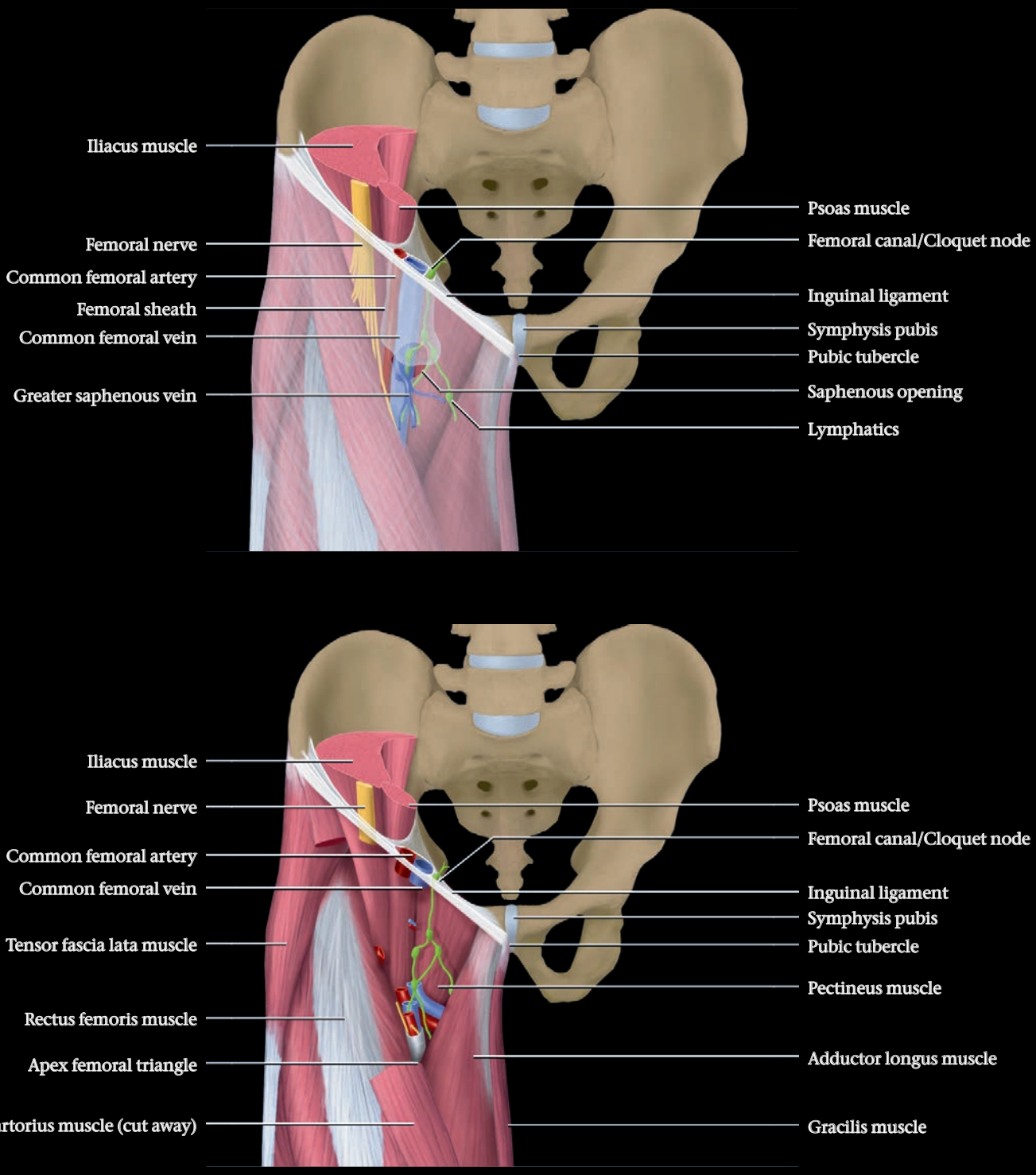
Inguinal Canal
- Entrance: **Deep inguinal ring**
  - Located midinguinal ligament
  - Opening of evaginated transversalis fascia through which spermatic cord/round ligament pass
- Exit: **Superficial inguinal ring**
  - Division of external oblique aponeurosis lateral to pubic tubercle
- Contents: Ilioinguinal nerve; male: Spermatic cord; female: Round ligament; associated vessels
  - Covered by evaginated transversalis fascia

Adductor Musculature
- **Adductor longus muscle**: Thin tendon arises from medial superior pubic ramus
  - Overlies origins of gracilis, adductor brevis, and magnus muscles
- **Gracilis muscle**: Origin from anterior aspect of symphysis pubis and medial aspect of inferior pubic ramus
  - Origin medial to adductor brevis muscle, deep to adductor longus muscle

Groin Nodes
- 2 groups of groin lymph nodes
- Superficial inguinal nodes
  - Lie in subcutaneous tissues below inguinal ligament and alongside great saphenous vein
  - Subdivided into 3 groups of lymph nodes
    - Inferior group are located distal to saphenous opening and receive drainage from lower limb
    - Superolateral group are located lateral to saphenous opening and receive drainage from lateral buttock and lower anterior abdominal wall regions
    - Superomedial group are located medial to saphenous opening and receive drainage from perineum and external genitalia
- Deep inguinal nodes
  - 3-5 nodes located in femoral triangle just medial to femoral vein
  - Cloquet node is the most proximal of deep inguinal lymph nodes located just below inguinal ligament

ANATOMY IMAGING ISSUES

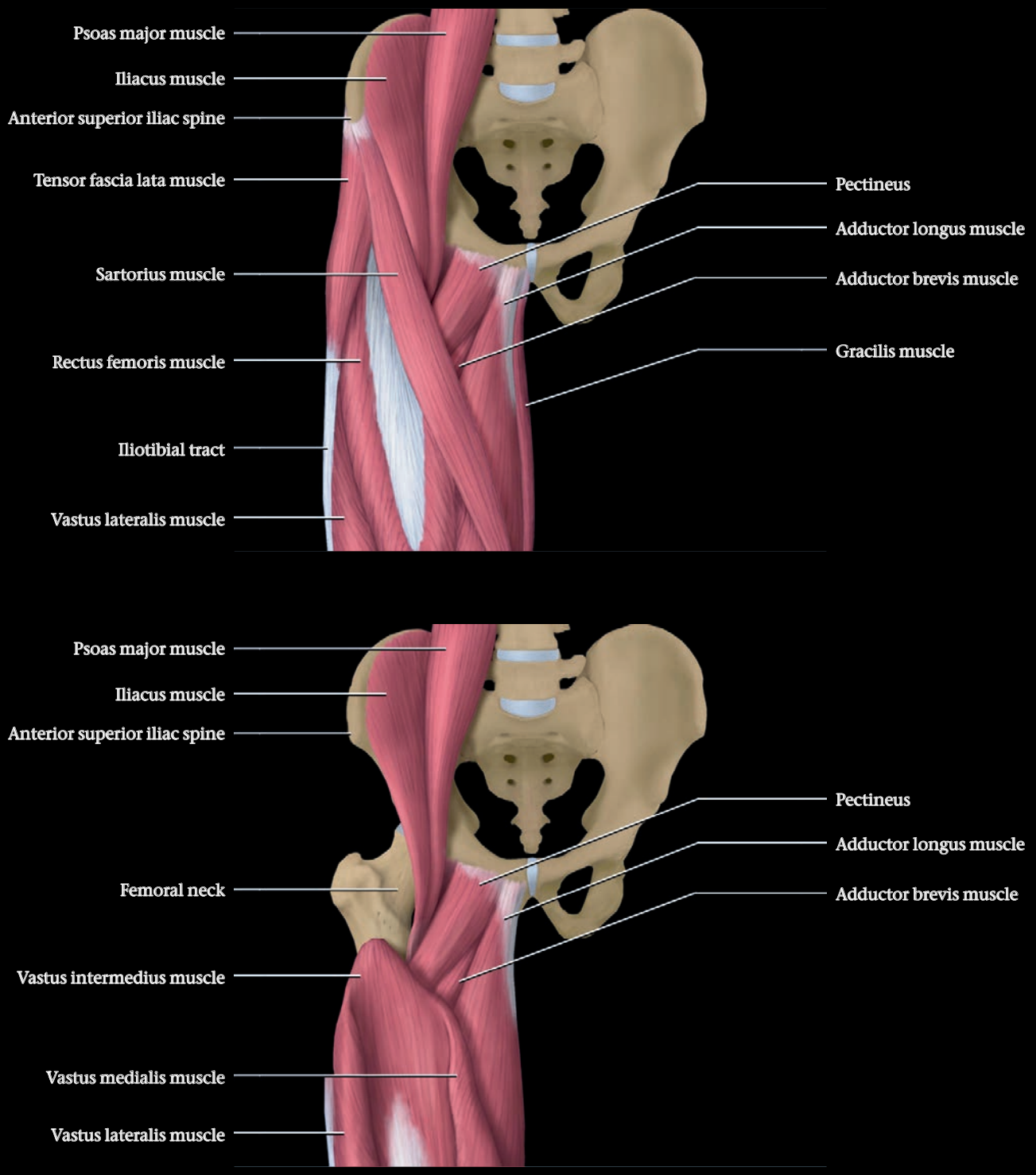
Imaging Recommendations
- Usual imaging pathway for assessing groin pathology is radiography followed by ultrasound
- If this does not provide necessary information, MR is next best investigation for most groin pathology



(Top) *The boundaries of the femoral triangle can be remembered by the mnemonic 'SAIL' for Sartorius, Adductor longus, and Inguinal Ligament. The contents of the femoral triangle from lateral to medial (remembered by the mnemonic 'NAVeL') are the femoral nerve, femoral artery and vein, and lymphatics. The nerve lies superficial to the iliopsoas muscle. The fascia lata encases the structures of the thigh. The femoral sheath is the fascial covering over the proximal vessels. At the cut away proximal boundary, note the septa dividing the sheath into compartments. The femoral canal is the medial compartment.* ***(Bottom)*** *Femoral triangle is shown after removal of the fascia lata, sartorius muscle, and the vessels. The apex of the triangle is at the crossing of the sartorius and adductor longus muscles. The pectineus, adductor longus, and iliopsoas muscles form the floor of the triangle.*

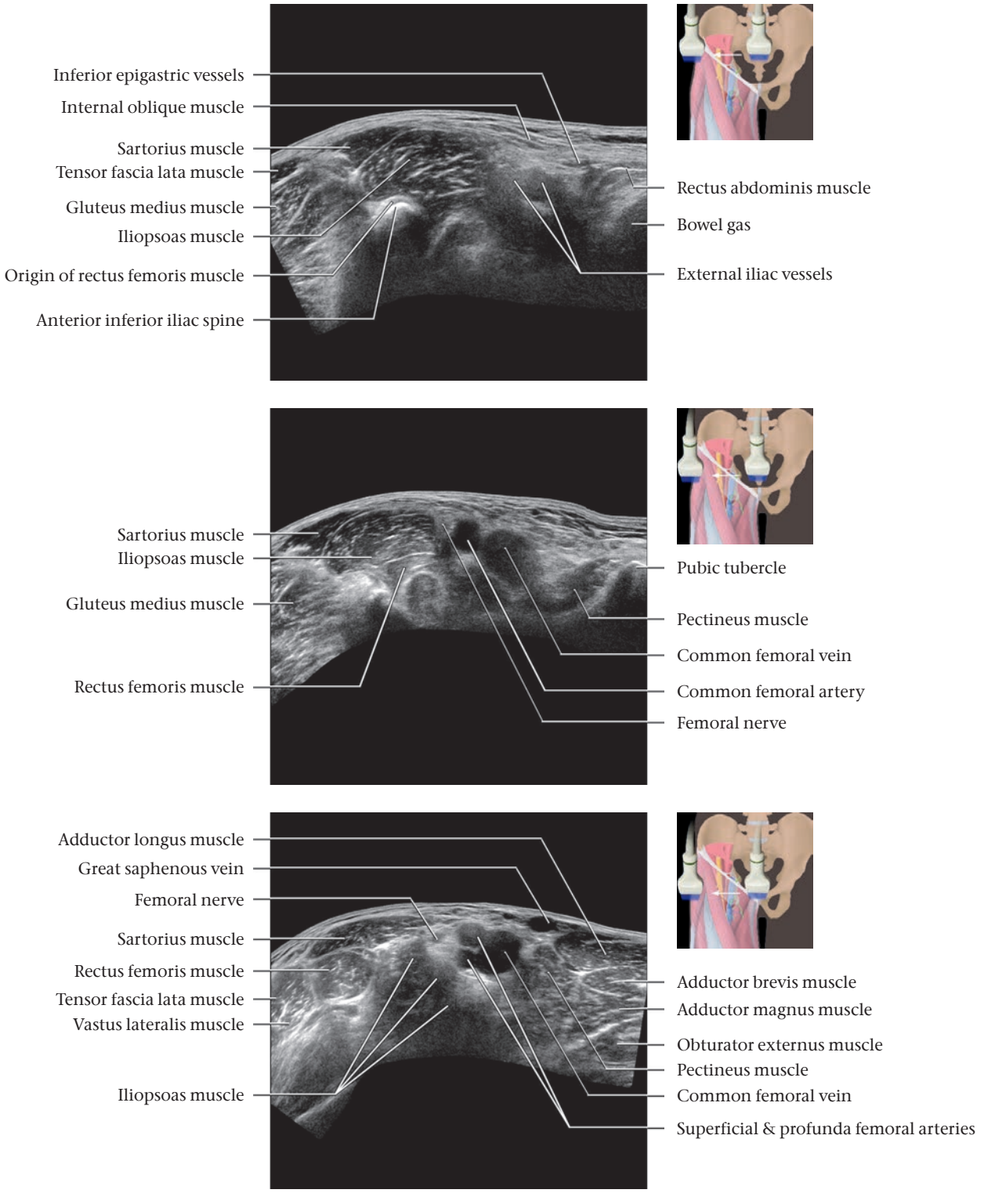
GROIN

GRAPHICS, GROIN MUSCLES



(Top) *Superficial muscles of the groin are shown. The most lateral muscle is the sartorius; its oblique course is easily appreciated. The psoas major and iliacus muscle exit from the pelvis toward the lesser trochanter. On the medial side, the most medial muscle is the gracilis. The adductor brevis muscle is deep to the adductor longus and pectineus muscles.* ***(Bottom)*** *After removing the superficial layer of muscles, the floor of the femoral triangle is better appreciated. The iliopsoas muscle dives deeply to its trochanteric insertion. The adductors fan out laterally from their pubic origin and constitute the major medial component at a midthigh level. The adductor magnus is in a deeper and more posterior position.*

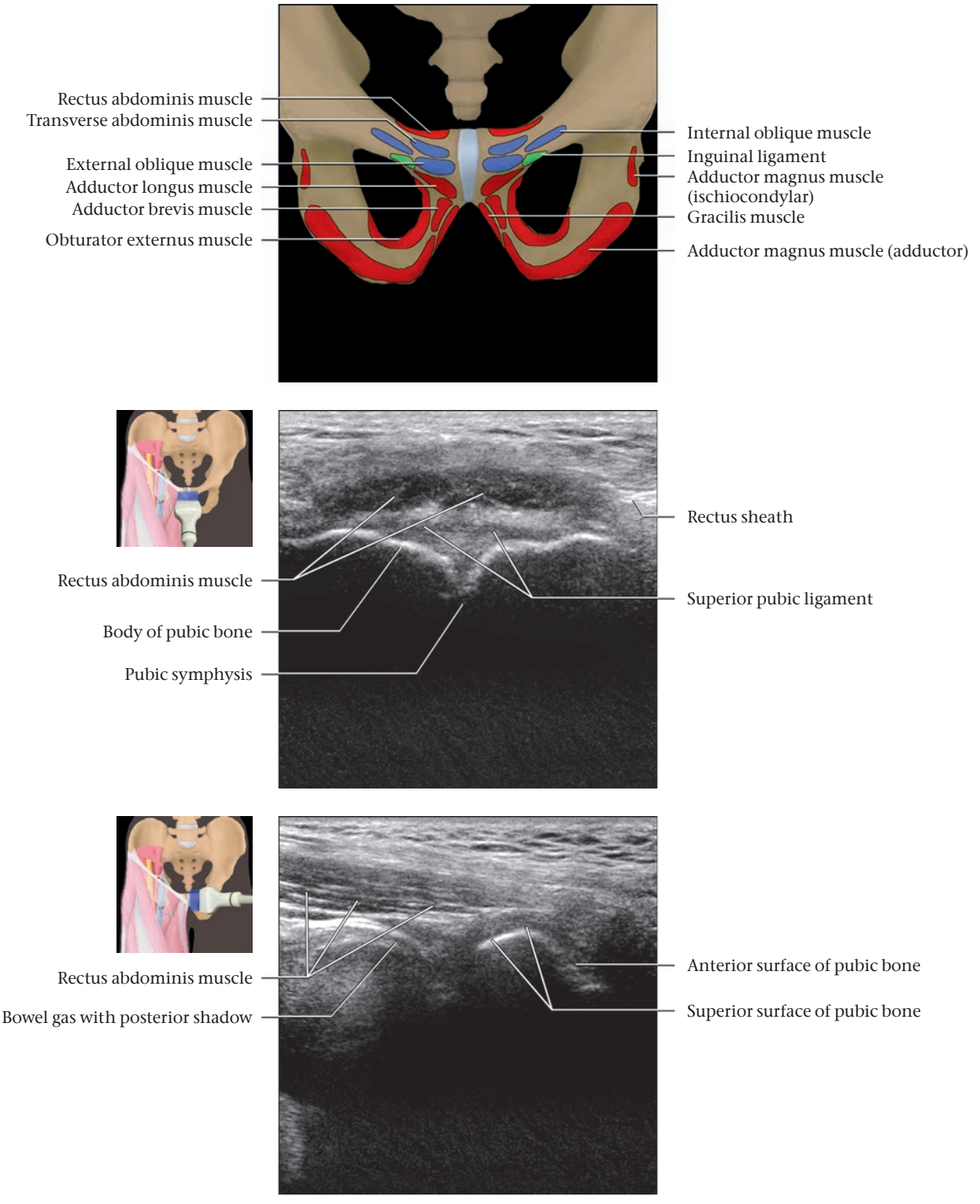
GROIN OVERVIEW



(Top) *Series of transverse panoramic scans show the groin. At this higher level, the lateral components of the groin include the sartorius and iliopsoas muscles, and at the medial boundary, the rectus abdominis muscle. At this level, where most structures are above the inguinal ligament, there is bowel (containing gas, which produces shadowing artifact). At this level, vessels are named external iliac vessels.* ***(Middle)*** *At a lower level, through the pubic bone, the vessels have moved superficially after passing under the inguinal ligament and now become the common femoral vessels. Bowel is not normally present at this level; instead, pectineus muscle and superior pubic ramus form the floor.* ***(Bottom)*** *Further inferiorly, the adductor muscles become the major medial component. Femoral vessels divide into superficial and profunda branches.*

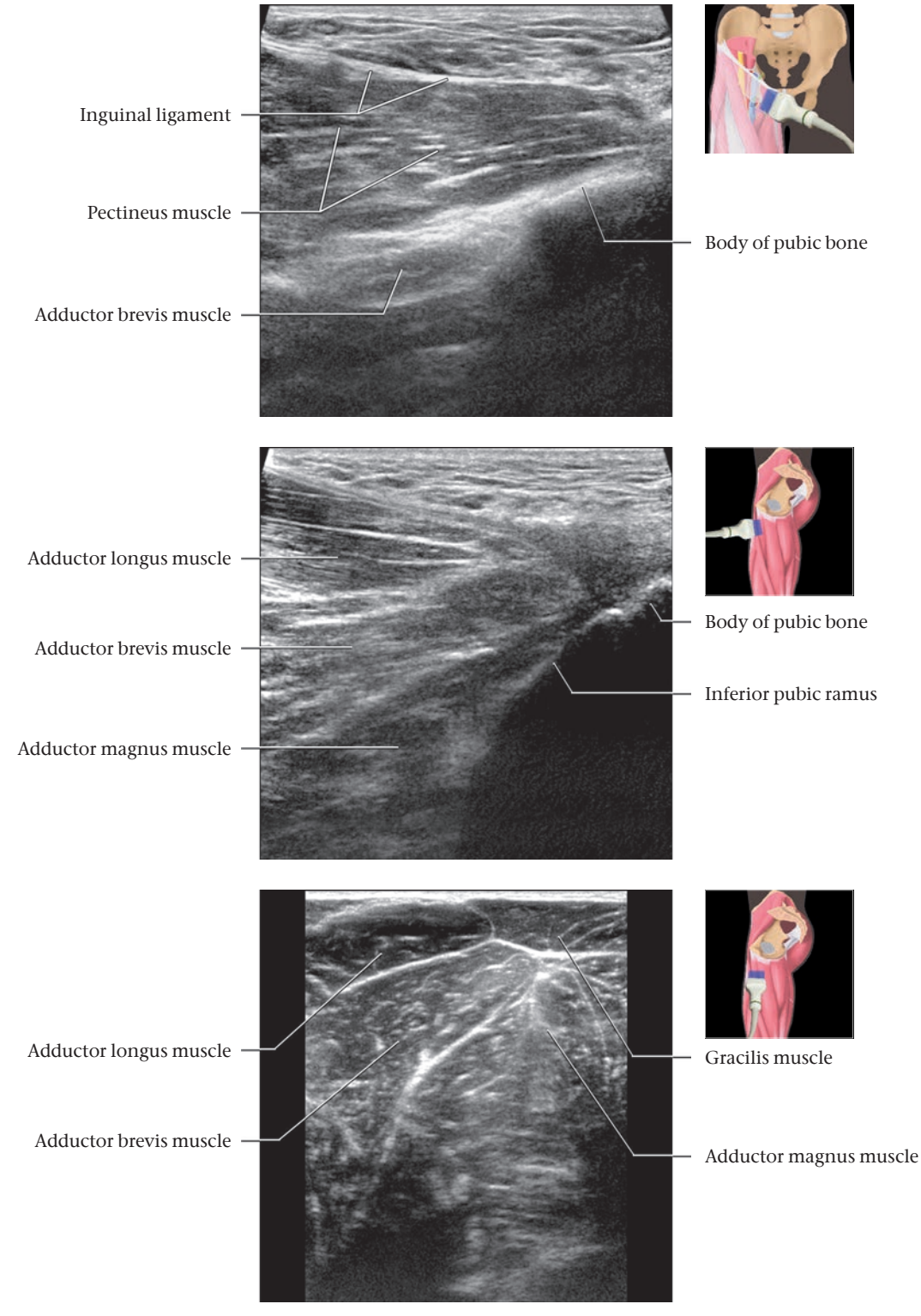
GROIN

MIDLINE GROIN



(Top) *Anterior view shows the anterior pelvis and the associated muscle attachments. A number of muscles take origin or insert onto the anterior aspect of the pelvis. These muscles aid in movement and stabilization of the trunk as well as movement and stabilization of the leg and form the medial components of the groin.* ***(Middle)*** *Transverse scan at the superior aspect shows pubic symphysis. The superior pubic ligament runs horizontally across the symphysis, deep to the rectus abdominis muscle origin.* ***(Bottom)*** *Sagittal image shows the lower rectus abdominis originating from the superior surface of pubic bone (pubic crest). Deep to the rectus abdominis muscle is the peritoneal cavity and bowel. Bowel gas produces posterior shadowing artifact, which obscures deeper structures.*

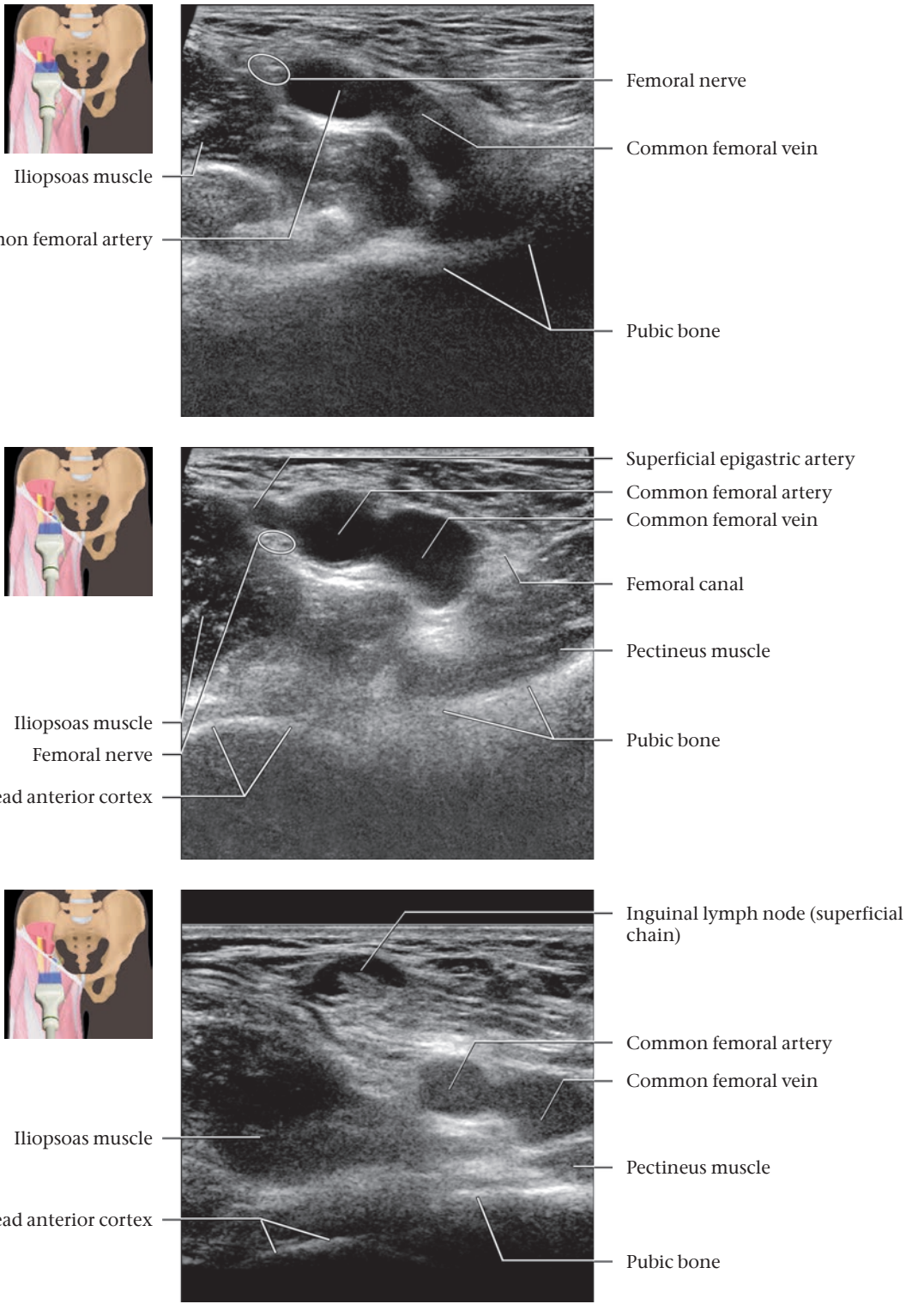
MEDIAL GROIN



(Top) *Series of (oblique) transverse scans through the adductor muscles are shown. Superiorly, the pectineus muscle originates from the pectineal line (which is a ridge on the superior ramus of the pubic bone) & runs laterally to insert on the pectineal line of the proximal femur. The pectineal line of the proximal femur lies between the lesser trochanter and the linea aspera. The pectineus muscle runs lateral to the adductor longus muscle & superficial to the adductor brevis muscle.* ***(Middle)*** *Slightly inferiorly and scanning more obliquely, the adductor longus, brevis, & magnus can be seen originating from the pubic body & inferior ramus. Scanning this region requires thigh abduction & balancing the transducer head on the bony landmark. From here, individual muscles can be traced inferolaterally. Note that the scout image is a graphic in this sagittal plane.* ***(Bottom)*** *Oblique transverse scan of adductors using a medial approach is shown. Adductor longus & gracilis muscles form superficial layer; adductor brevis & magnus muscles run deeper. All muscles run inferolaterally to their femoral insertions.*

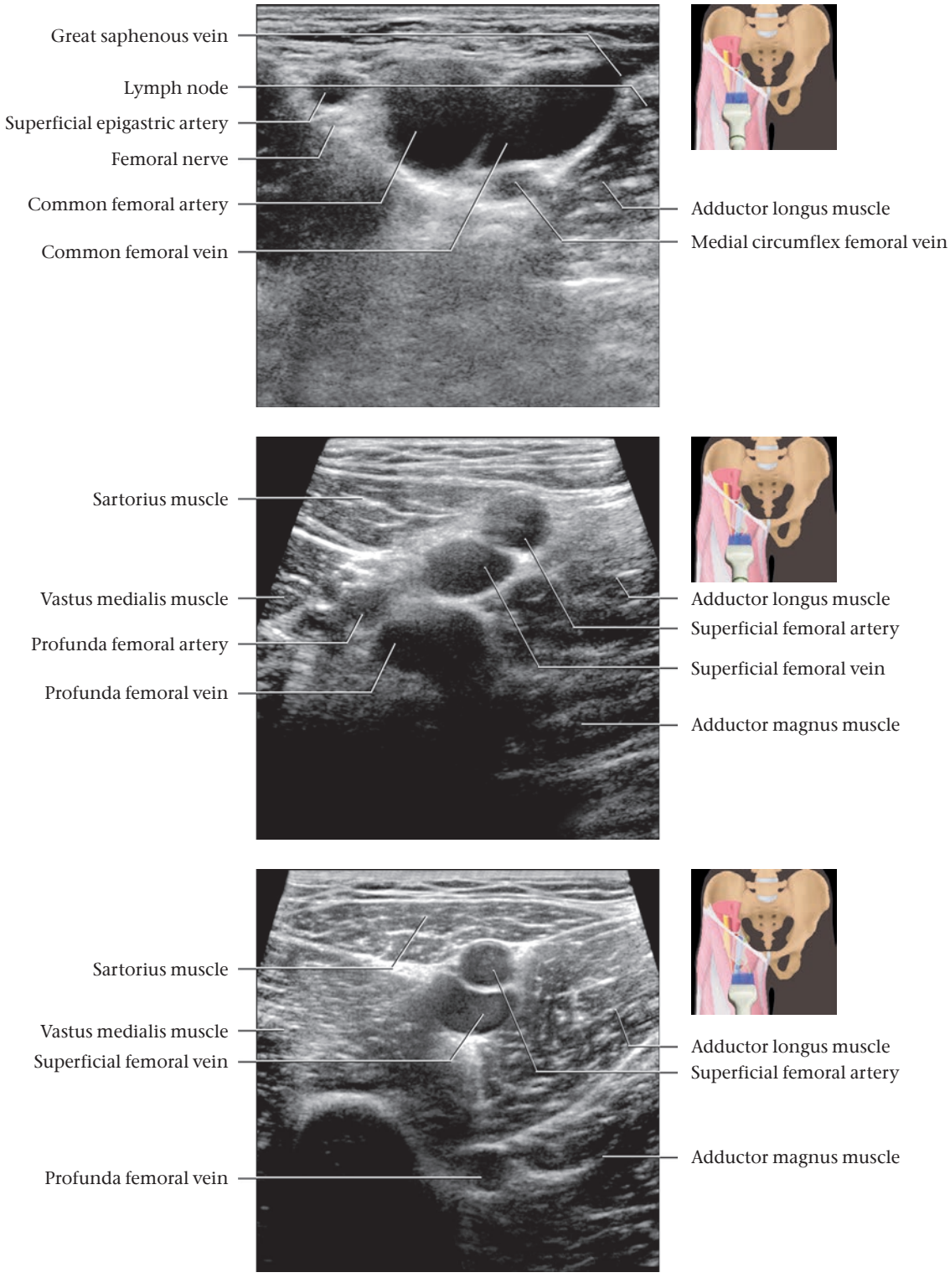
GROIN

CENTRAL GROIN, FEMORAL TRIANGLE



(Top) *Series of transverse scans through the femoral triangle are shown. Above the inguinal ligament, the femoral nerve, artery, & vein run medial to the iliopsoas tendon. The pubic bone acts as a hard support for the iliopsoas and pectineus muscular floor.* ***(Middle)*** *Slightly inferiorly, below the inguinal ligament, the femoral triangle commences. The mnemonic for the contents is NAVeL, standing for femoral nerve, common femoral artery, common femoral vein, & lymph nodes (within femoral canal). The pectineus muscle forms the floor of femoral triangle. This floor is supported by the pubic bone & hip joint.* ***(Bottom)*** *In addition to lymph nodes in the femoral canal, lymph nodes are frequently seen superficially (the superficial inguinal chain) in the subcutaneous tissue.*

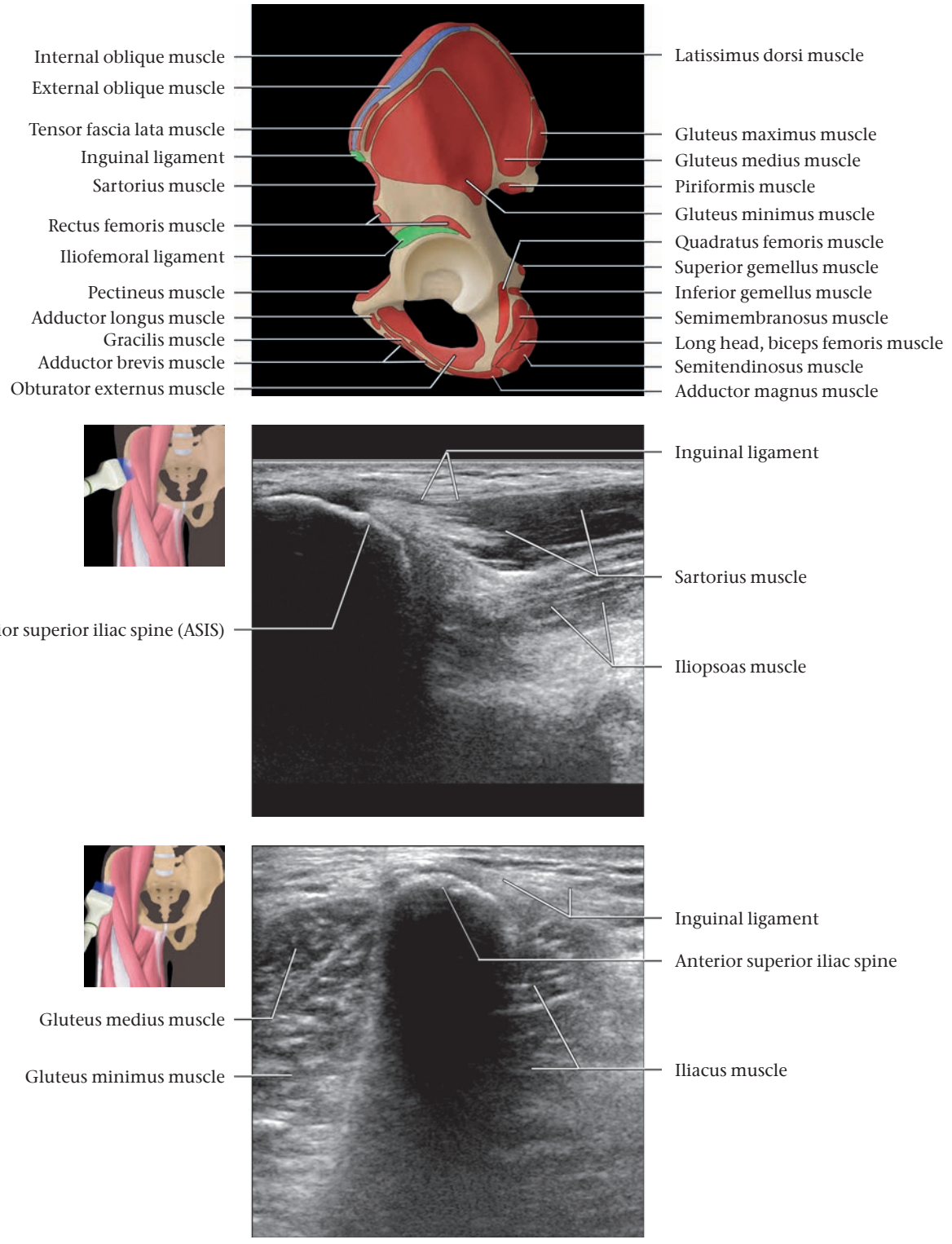
CENTRAL GROIN, FEMORAL TRIANGLE



(Top) *Further inferiorly & still within the femoral triangle, the great saphenous vein perforates the anterior wall of the femoral sheath to enter the femoral vein. Also, the floor changes from the pectineus to adductor longus muscle, with no bony support.* ***(Middle)*** *Transverse scan is shown at the apex of the femoral triangle, defined as where the sartorius muscle becomes the roof of the femoral triangle. Just before exiting the femoral triangle, the femoral vessels divide into superficial and profunda branches.* ***(Bottom)*** *Transverse scan shows the adductor canal. Distal to the femoral triangle, the superficial femoral vessels continue within a muscular conduit, the adductor canal. The groin muscles (the adductor longus and magnus muscles) form the medial wall and floor of this canal.*

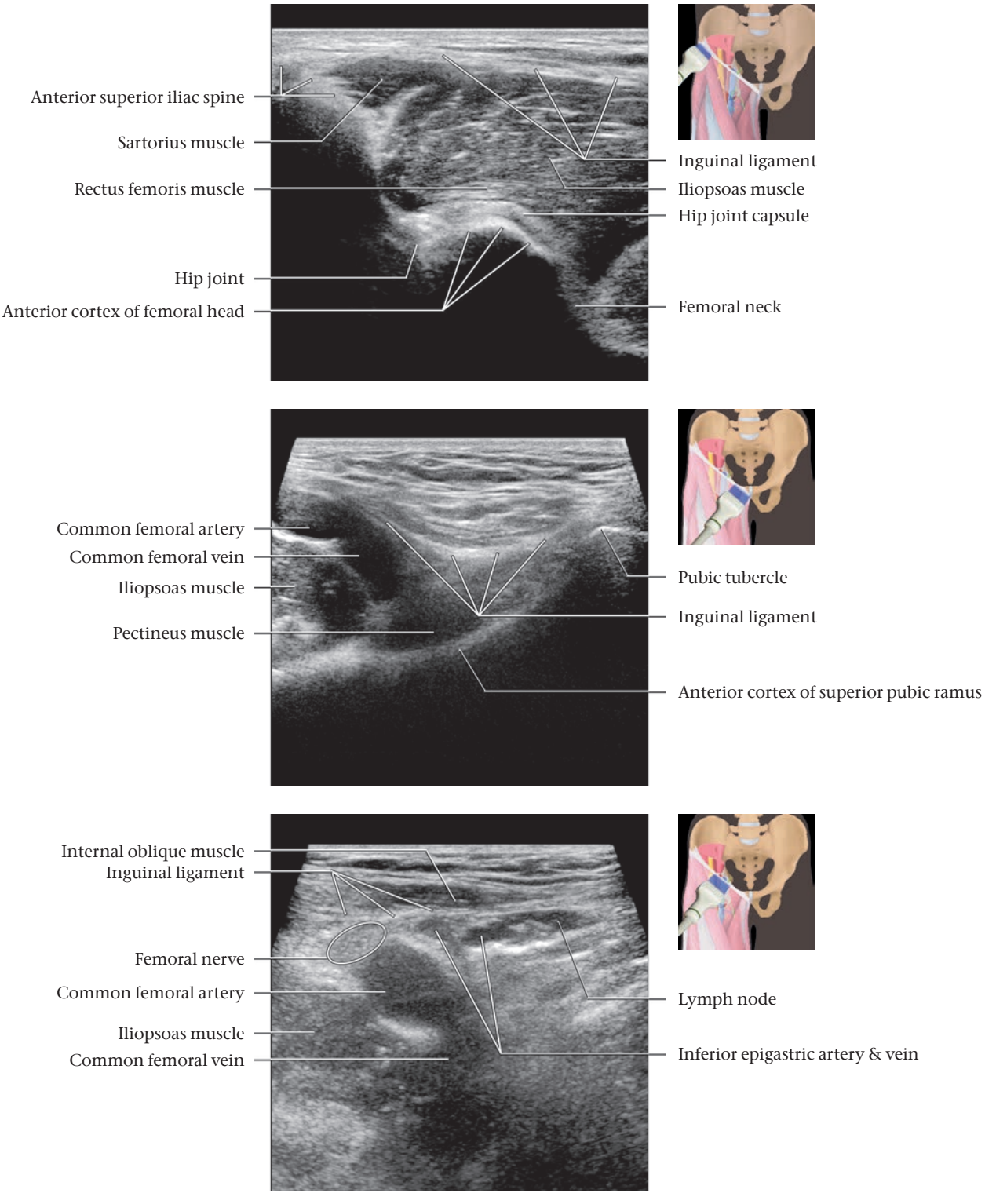
GROIN

LATERAL GROIN, ANTERIOR SUPERIOR ILIAC SPINE



(Top) *Muscle and ligament attachments to the external surface of the pelvis are shown. Note the relatively small origin of the tendon of the adductor longus muscle. The adductor brevis muscle is just deep to the longus muscle. The origin of the gracilis muscle is lateral to the adductor brevis muscle. The adductor magnus muscle has a broad origin with its posterior fibers in close proximity to the hamstring tendon origins.* ***(Middle)*** *Oblique sagittal scan of ASIS shows the origin of the sartorius muscle (longest muscle in body). This slender muscle runs inferomedially over the iliopsoas muscle, covers the adductor canal, & inserts at the proximal tibia as part of the pes anserinus.* ***(Bottom)*** *Coronal scan of the anterior superior iliac spine shows division of muscle groups by this bone. Gluteal muscles lie lateral & hip flexors medial. The inguinal ligament originates here & runs inferomedially to the pubic tubercle.*

ACROSS GROIN, INGUINAL LIGAMENT



(Top) *Oblique transverse scan of the upper groin shows the inguinal ligament attachment on the anterior superior iliac spine, with the sartorius muscle originating immediately inferior. The inguinal ligament runs inferomedially and covers the iliopsoas muscle.* ***(Middle)*** *Oblique transverse scan along the medial aspect of the inguinal ligament is shown. Medially, the inguinal ligament forms the roof of the femoral canal (covering the femoral vessels & nerve). It then runs over the pectineus muscle to insert on the pubic tubercle.* ***(Bottom)*** *Superficially focused oblique transverse scan over the upper femoral triangle shows the inguinal ligament forming its roof. Inferior epigastric vessels branch out from the femoral vessels and run superomedially. Clinically, the inferior epigastric vessels define the lateral boundary of direct inguinal hernias. Inguinal hernias that emerge lateral to the inferior epigastric vessels are considered indirect.*

GLUTEAL MUSCLES

TERMINOLOGY

Abbreviations

- Anterior superior iliac spine (ASIS)
- Artery (a.)
- Function (F)
- Insertion (I)
- Ligament (l.)
- Muscle (m.)
- Nerve supply (N)
- Origin (O)
- Vein (v.)

IMAGING ANATOMY

Gluteal Muscles

- Components: Gluteus maximus, gluteus medius, gluteus minimus, tensor fascia lata, piriformis, obturator internus and externus, superior and inferior gemellus, quadratus femoris
- Common functions: Hip abduction, external rotation
- **Inferior gemellus**
  - O: Ischial tuberosity
  - I: Piriformis fossa
  - N: Nerve to quadratus femoris muscle
  - F: Hip external rotation, weak abduction
- **Superior gemellus**
  - O: Ischial spine
  - I: Piriformis fossa
  - N: Nerve to obturator internus muscle
  - F: Hip external rotation, weak abduction
- **Gluteus maximus**
  - O: Posterior gluteal line (ilium), posterior sacrum and coccyx, sacrotuberous ligament
  - I: Iliotibial tract, gluteal tuberosity
  - N: Inferior gluteal
  - F: Hip extension, abduction, and external rotation
- **Gluteus medius**
  - O: Between anterior and posterior gluteal lines (ilium)
  - I: Lateral and posterosuperior facets of greater trochanter
  - N: Superior gluteal
  - F: Hip abduction and internal rotation
- **Gluteus minimus**
  - O: External ilium between anterior and inferior gluteal lines
  - I: Anterior facet of greater trochanter
  - N: Superior gluteal
  - F: Hip abduction and internal rotation
- **Obturator internus**
  - O: Internal surface of obturator foramen and membrane
  - I: Piriformis fossa (joins with gemelli tendons)
  - N: L5, S1, S2
  - F: Hip external rotation, weak abduction
- **Obturator externus**
  - O: Edge of obturator foramen and obturator membrane
  - I: Posterior aspect of femur in trochanteric fossa
  - N: Obturator nerve
  - F: Lateral rotation of hip
- **Piriformis**
  - O: Anterior sacrum, sacrotuberous ligament
  - I: Greater trochanter (may fuse with obturator internus and gemellus muscles)
  - N: S1, S2
  - F: Hip external rotation, assists abduction
- **Tensor fascia lata**
  - O: External lip anterior iliac crest, external ASIS
  - I: Iliotibial tract
  - N: Superior gluteal
  - F: Hip flexion, abduction, and weak internal rotation
- **Quadratus femoris**
  - O: Lateral ischial tuberosity
  - I: Quadrate line, intertrochanteric crest of femur
  - N: L4, L5, S1
  - F: Strong hip external rotation

Rotator Cuff of Hip

- Gluteus medius and minimus tendons, trochanteric bursa, subgluteus medius and minimus bursae

Bursa

- Trochanteric
  - Greater trochanter and gluteus maximus muscle
- Ischiogluteal
  - Ischial tuberosity and gluteus maximus muscle
- Subgluteus medius
  - Greater trochanter and gluteus medius
- Subgluteus minimus
  - Greater trochanter and gluteus minimus muscle
- Gluteofemoral
  - Iliotibial tract and vastus lateralis muscle
- Obturator internus
  - Muscle and ischium
- Obturator externus
  - Synovial protrusion beneath inferior border

Piriformis Fossa

- Between posterior femoral neck and posterior medial surface of greater trochanter
- Insertion site for piriformis, superior and inferior gemelli, obturator internus

Ischial Tuberosity

- Covered by gluteus maximus muscle when hip extended, uncovered in hip flexion
- Origin of hamstrings and adductor magnus muscles

Sacroiliac Joint

- Anterior synovial joint
- Posterior syndesmosis: Tuberosities of sacrum and ilium
- Function: Primarily weight transfer axial to appendicular skeleton
  - Limited gliding and rotation
- Widening anteriorly can occur without instability
- Posterior widening indicates instability
- **Sacroiliac ligaments**
  - **Interosseous sacroiliac**: Within syndesmotic joint
    - Between tuberosities of ilium and sacrum
    - Oriented superiorly and laterally
    - Weight transferred to sacrum; sacrum displaced inferiorly; force transmitted to ligaments; ligaments pull ilii inward, and compress sacrum and interlocking surfaces of sacroiliac joints
    - Extremely strong
  - **Anterior sacroiliac**: Weak ligaments
    - Mainly anterior joint capsule

- **Posterior sacroiliac**: Posterior fibers interosseous ligament
  - **Short dorsal sacroiliac**: Horizontal; lateral sacral crest S1 and S2 to posterior iliac crest
  - **Long dorsal sacroiliac**: Vertical oblique; posterior superior iliac spine to lateral sacral crest S3, S4

Posterior Sacroiliac Ligaments of Pelvis

- Primary stabilizers of pelvis
  - Little contribution from anterior structures
- Resist rotational forces and vertical shear
- **Sacrotuberous**: Superior and inferior posterior iliac spines, sacrum, and coccyx to ischial tuberosity
- **Sacrospinous**: Lateral sacrum and coccyx to ischial spine
- **Iliolumbar**: Tip of L5 transverse process to iliac crest
- **Sacroiliac ligaments**: Interosseous, long and short dorsal

Greater Sciatic Foramen

- Greater sciatic notch converted to foramen by sacrospinous ligament
- Contents: Nerves, vessels, piriformis muscle
- Passageway from pelvis to thigh
  - Structures identified as exiting pelvis above or below piriformis muscle
    - Above: Superior gluteal artery, vein and nerve
    - Below: Pudendal nerve, internal pudendal artery and vein, nerve to obturator internus, sciatic nerve, inferior gluteal artery, vein and nerve, posterior cutaneous nerve of thigh, nerve to quadratus femoris muscle
  - Relationship of structures
    - Most medial: Pudendal nerve
    - Most lateral: Sciatic nerve
    - Nerve to quadratus femoris muscle deep to sciatic nerve
- **Inferior gluteal artery**
  - Larger terminal branch anterior division internal iliac artery
  - Passes between S1 and S2 or S2 and S3
  - Exits pelvis inferior to piriformis muscle
  - Posteromedial to sciatic nerve
  - Prenatally continuous with popliteal artery; remnant is artery to sciatic nerve
  - Supplies gluteus maximus, obturator internus, quadratus femoris, superior hamstrings muscles
  - **Inferior gluteal vein** travels with artery, drains into internal iliac vein
- **Inferior gluteal nerve**
  - Branch of sacral plexus
  - Exits pelvis inferior to piriformis muscle
  - Posterior to sciatic nerve
- **Superior gluteal artery**
  - Continuation of posterior division of internal iliac artery
  - Passes between lumbosacral trunk and S1
  - Exits pelvis superior to piriformis muscle
  - Superficial branch supplies gluteus maximus muscle
  - Deep branch supplies gluteus medius and minimus, tensor fascia lata muscles
  - **Superior gluteal vein** travels with artery, drains into internal iliac vein
- **Superior gluteal nerve**
  - Branch of sacral plexus
  - Exits pelvis superior to piriformis muscle
- **Sciatic nerve**
  - Exits pelvis inferior to piriformis muscle
  - Most lateral structure
- **Pudendal nerve and internal pudendal vessels**
  - Exit inferior to piriformis muscle
  - Nerve most medial structure
- **Nerve to obturator internus muscle**
  - Exits pelvis inferior to piriformis muscle

Lesser Sciatic Foramen

- Lesser sciatic notch converted to foramen by intersection (crossing) with sacrotuberous and sacrospinous ligaments
- Contents
  - **Pudendal nerve and internal pudendal vessels**
    - Pass over sacrospinous ligament
    - Exit buttock, enter perineum
  - **Obturator internus muscle**

ANATOMY IMAGING ISSUES

Imaging Recommendations

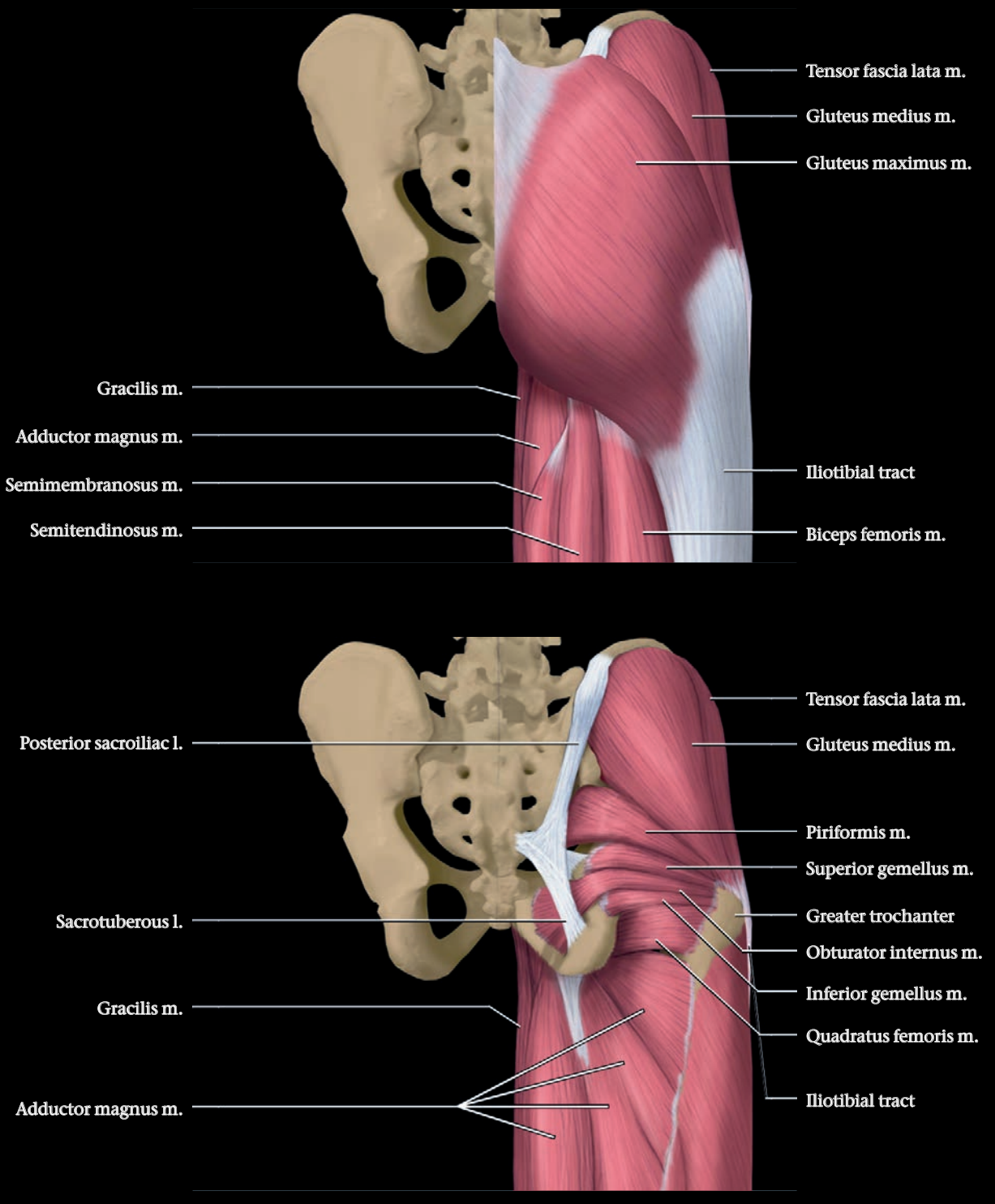
- US
  - Subcutaneous fat in gluteal region can be thick and mistaken for muscle
  - Look for investing fascia and fiber orientation to identify muscle layer
  - Anisotropy gives gluteal muscles varying echogenicity due to different orientation of fibers
    - Allows clear distinction between muscles
    - Lesions may be better demonstrated/detected by scans along and across muscle fibers to make lesion more conspicuous
  - Iliac crest, greater trochanter, and ischial tuberosity are important bony landmarks for orientation
  - Use of panoramic (extended field of view) images will help referring clinicians to understand location of a lesion
    - Panoramic images should be performed in standard anatomical planes to help interpretation
    - Landmarks, especially osseous (e.g., iliac crest, sacrum, ischial tuberosity), also help interpretation of a panoramic image
    - Panoramic images do not provide accurate measurements
    - Wide lesions are best assessed using dual screen/multiple contiguous images for a summated linear measurement
- MR
  - Diagnose masses, anatomic anomalies, other causes of nerve compression
  - Preferred modality for sacroiliitis
- CT
  - Mainly used for assessing bone and joint (sacroiliac) abnormalities

Imaging Pitfalls

- Lower frequency transducers (5 MHz or below) should be used initially in an examination to exclude deep-seated lesions

GLUTEAL MUSCLES

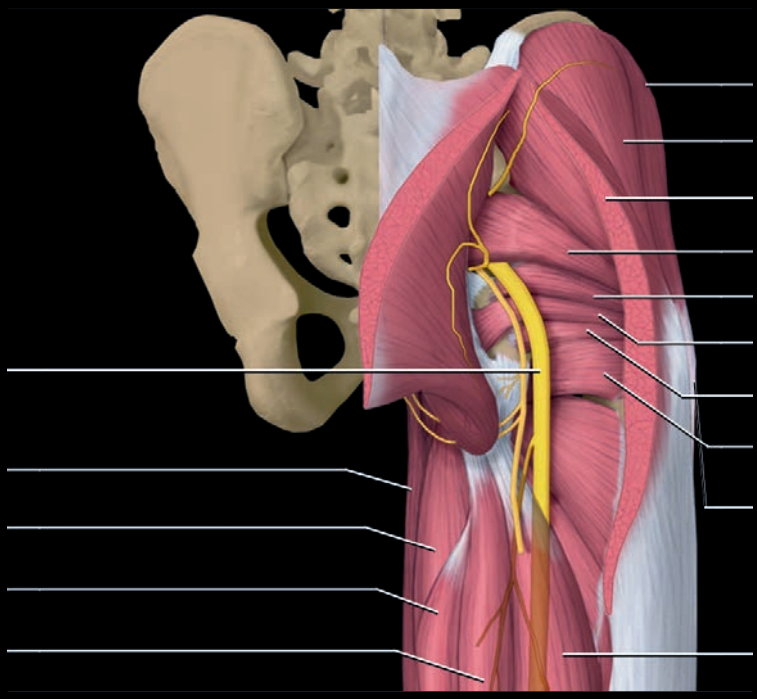
GRAPHICS, GLUTEAL MUSCLES

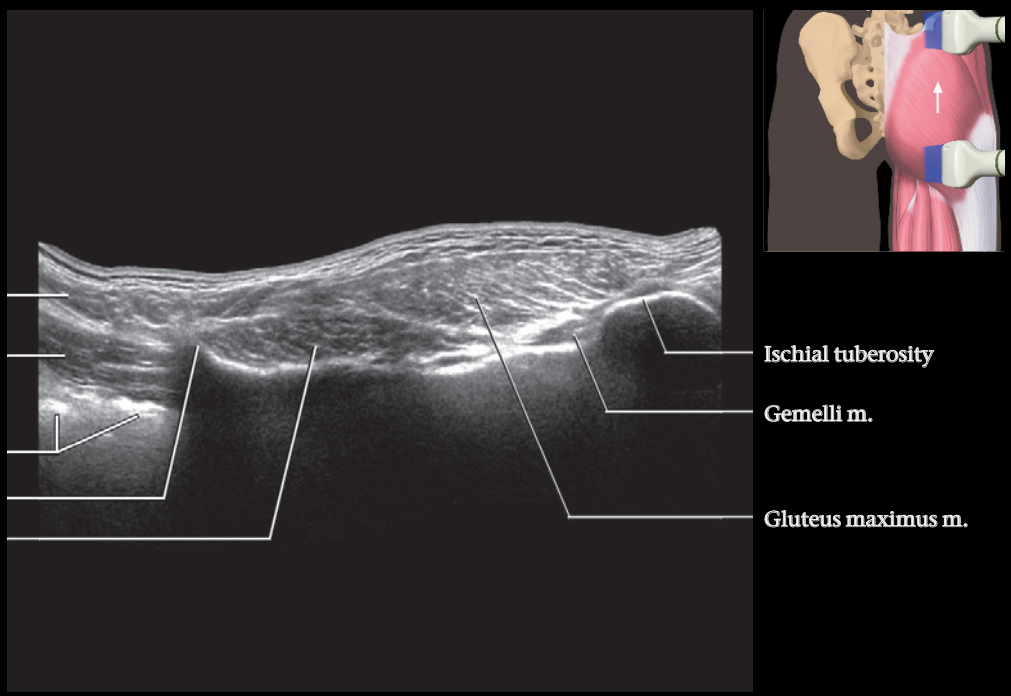


(Top) *The gluteus muscles from anterior to posterior and deep to superficial are the gluteus minimus, medius, and maximus. These muscles form the bulk of the gluteal region. The gluteus maximus, in particular, covers most of the deep gluteal structures.* ***(Bottom)*** *After removing the gluteus maximus, the deep muscles are visible: Piriformis, superior gemellus, obturator internus, inferior gemellus, and quadratus femoris. These all function as external rotators of the thigh. Note the piriformis muscle, which exits via the greater sciatic foramen, and the obturator internus muscle via the lesser sciatic foramen.*

GLUTEAL MUSCLES

GRAPHIC, SCIATIC NERVE & OVERVIEW, GLUTEAL

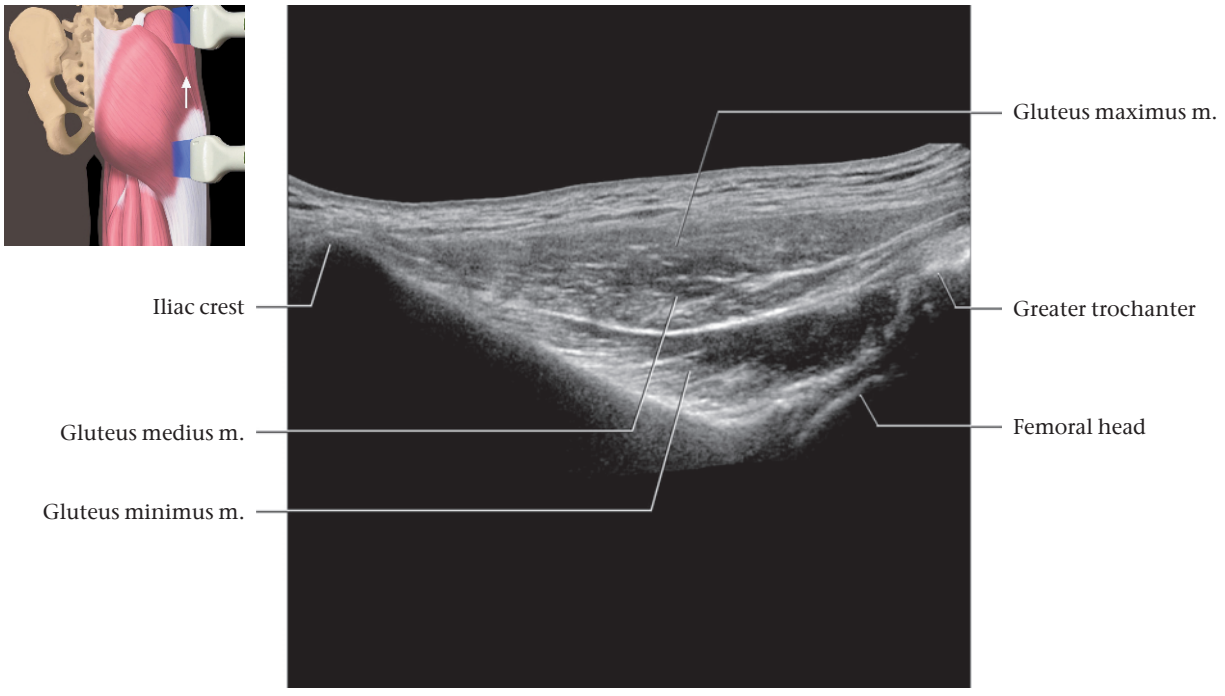


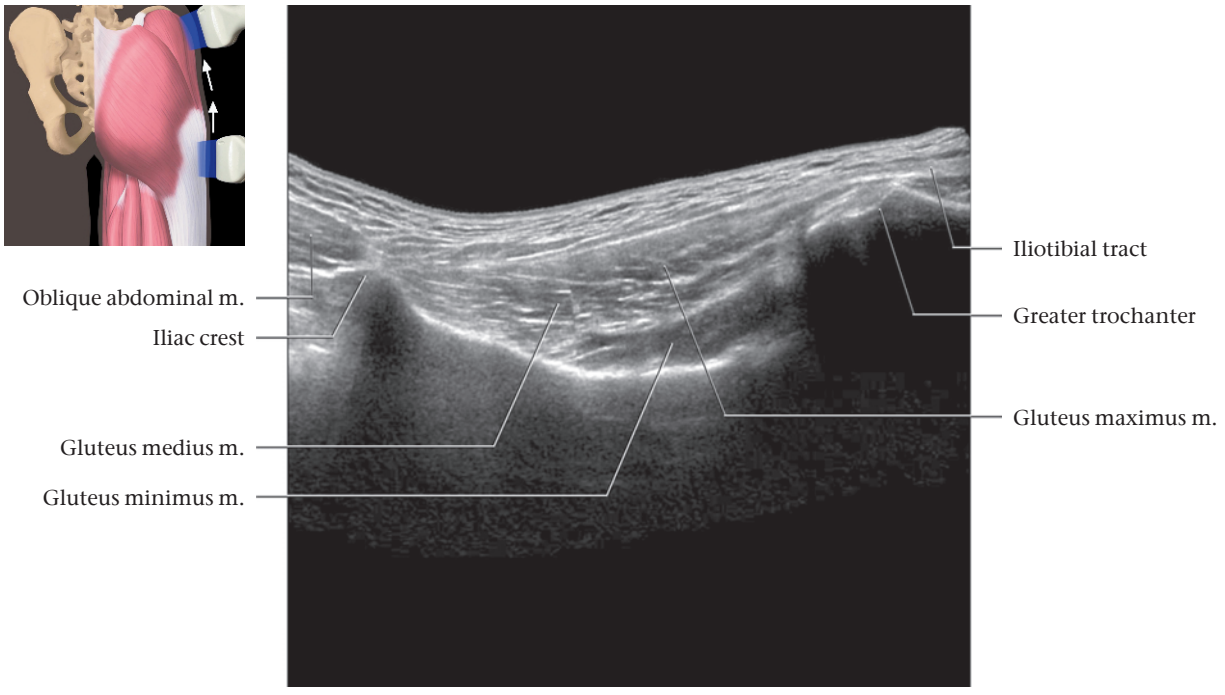


(Top) *The deep external rotators of the hip share an intimate relationship with the sciatic nerve, which emerges between the piriformis and superior gemellus muscles and then between the gluteus maximus and the rest of the deep external rotators. More distally, the sciatic nerve is covered by the biceps femoris muscle.* ***(Bottom)*** *Sagittal panoramic view shows the medial aspect of the gluteal region. The iliac crest separates the back muscles from the glutei. At this level, the gluteus maximus muscle forms the main muscle bulk. Inferiorly, the gluteus maximus runs across the surface of the ischial tuberosity in this extended (hip joint) position. Coverage is lost (gluteus maximus moves superiorly) when the hip joint is flexed and the ischial tuberosity is exposed.*

GLUTEAL MUSCLES

OVERVIEW, GLUTEAL REGION

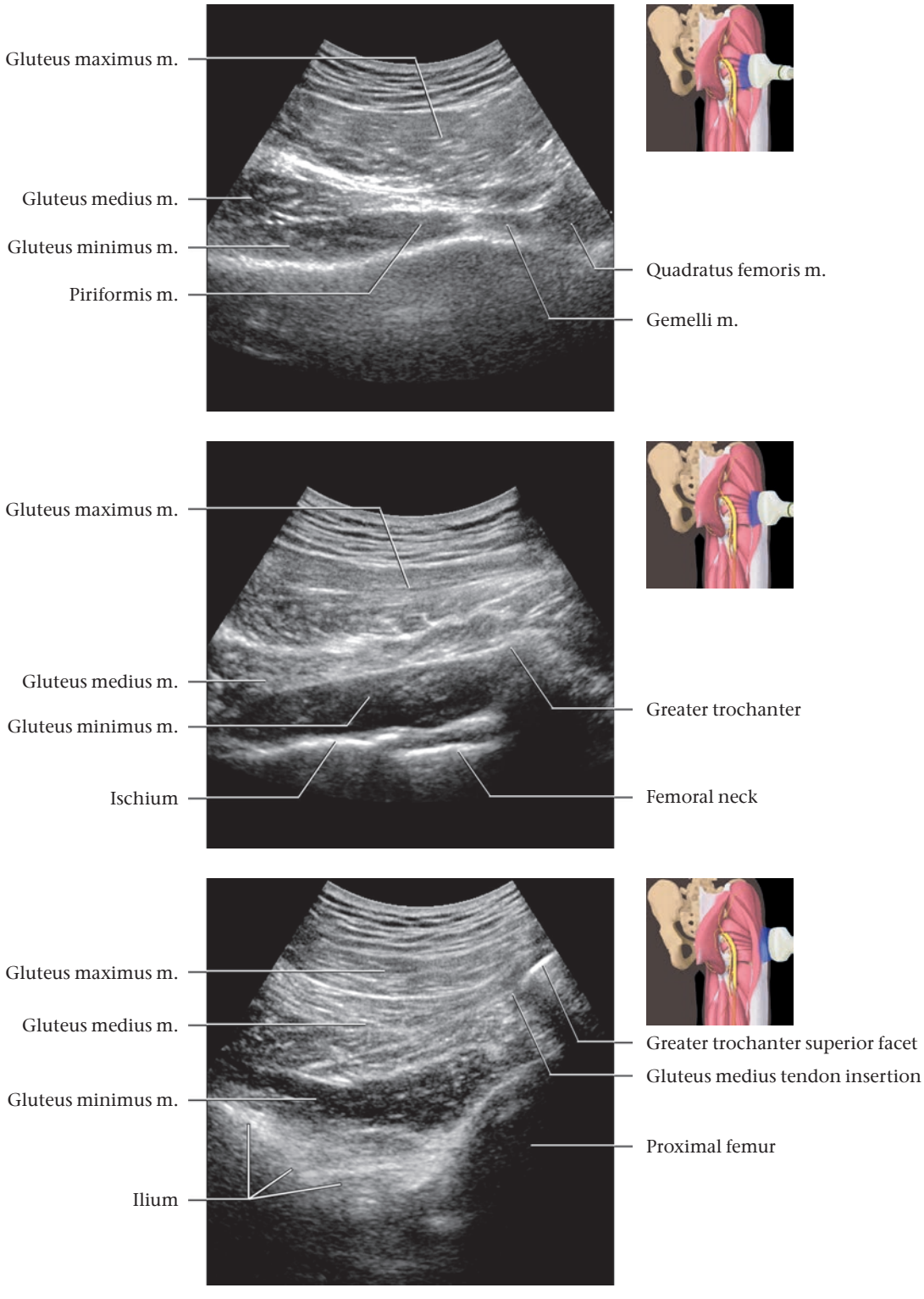




(Top) *Oblique sagittal panoramic view shows the lateral 1/2 of the gluteal region. The close relationship between the gluteus minimus muscle and the posterior aspect of the hip joint can be appreciated here. In this region, all 3 gluteal muscles are present and can be distinguished by their different echogenicity. The gluteus maximus muscle fibers are running approximately horizontally along the scan plane and, being most superficial, produce the highest echogenicity. The gluteus medius is running obliquely (lateral inferiorly) and thus shows short echogenic fibers. The gluteus minimus runs obliquely and almost horizontally towards the anterior facet of the greater trochanter. It is the deepest gluteal muscle and usually appears hypoechoic.* ***(Bottom)*** *Coronal panoramic view shows the gluteus medius and minimus muscles and their insertion on the greater trochanter. The iliotibial tract runs on the surface of the greater trochanter.*

GLUTEAL MUSCLES

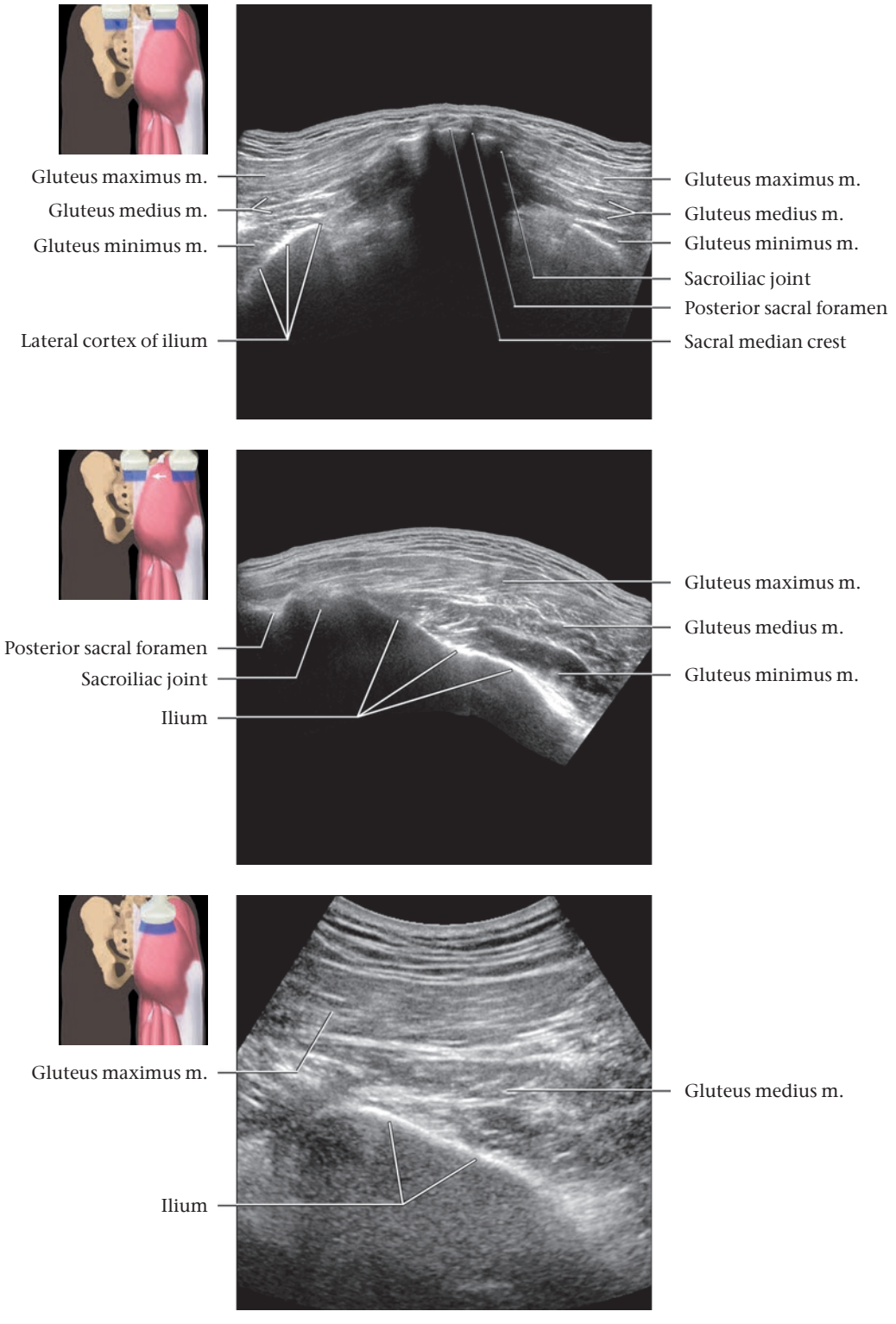
SAGITTAL GLUTEAL



(Top) *Oblique sagittal scan in the lateral 1/2 of the gluteal region shows the three gluteal muscles and their relationship with the deeper, small external rotators: piriformis, superior and inferior gemellus, and quadratus femoris muscles.* ***(Middle)*** *Further laterally, the femoral neck can be seen under the gluteus minimus. Again, the different echogenicity and echotexture of the three gluteal muscles can be appreciated.* ***(Bottom)*** *Further laterally, the gluteus medius tendon fibers insert onto the lateral and posterosuperior facets of the greater trochanter. The gluteus minimus tendon runs anteriorly under the gluteus medius to insert on the anterior facet of greater trochanter.*

GLUTEAL MUSCLES

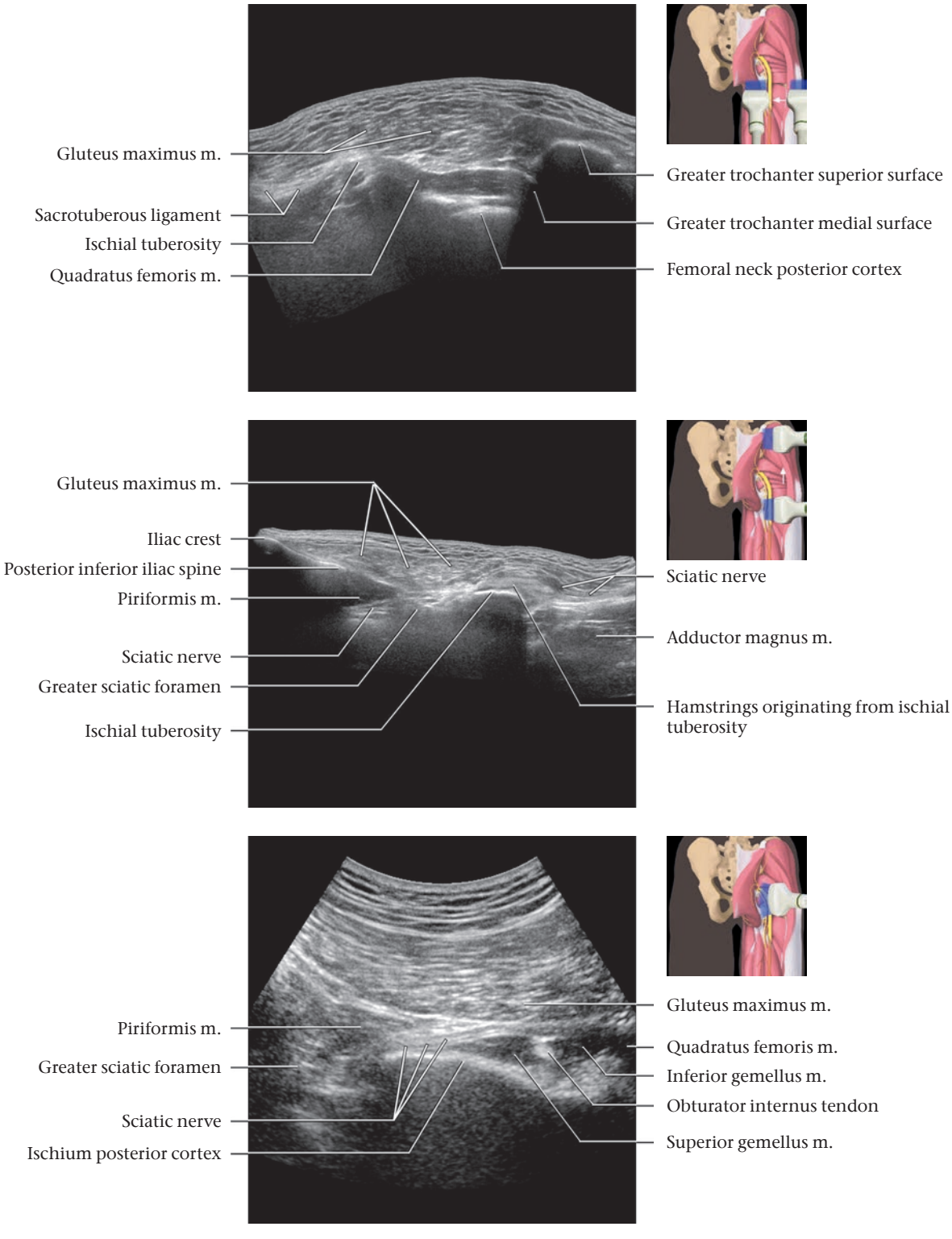
TRANSVERSE GLUTEAL



(Top) *Transverse panoramic scan is seen across the dorsal surface of the sacrum. This is the medial origin of the gluteus maximus muscle. Deep to this muscle, the gluteus medius and gluteus minimus muscles can be seen originating from the iliac surface.* ***(Middle)*** *Transverse panoramic view shows the right gluteal region. The 3 gluteal muscles show their signature difference in echogenicity and echotexture even in the horizontal plane.* ***(Bottom)*** *Transverse focused view of the medial gluteal region shows the fiber orientation of the different muscles. Those of the gluteus maximus are longer, as they run roughly horizontally compared to those of the gluteus medius. This orderly fiber pattern is helpful in detecting intra- and intermuscular lesions in the gluteal region (orderly fiber alignment tends to be disrupted in disease).*

GLUTEAL MUSCLES

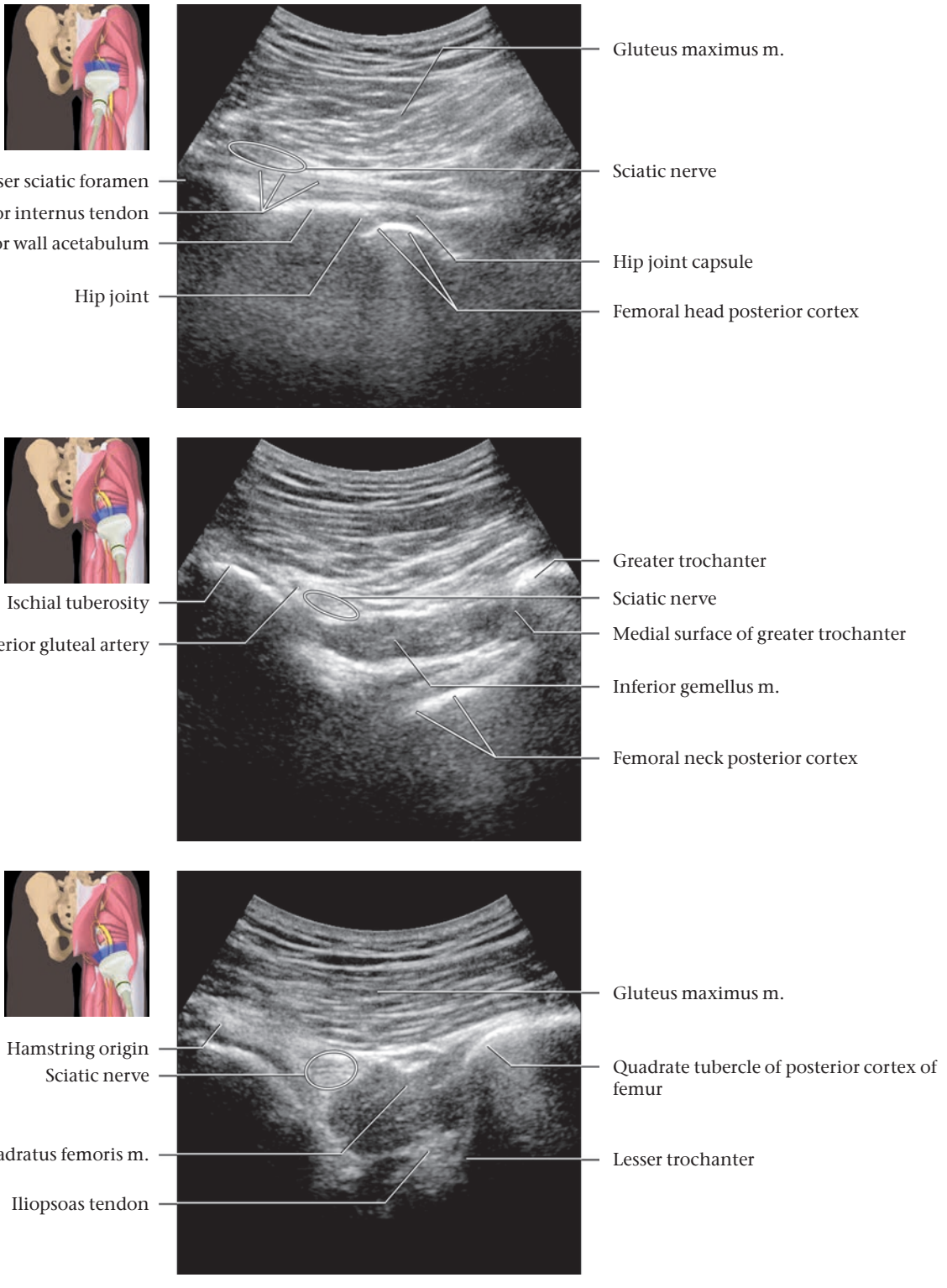
ISCHIAL REGION



(Top) *Transverse panoramic view shows the ischial region. The gluteus maximus forms most of the bulk at this lower gluteal level. Deep to this, small external rotators of the hip can be seen (in this scan, the quadratus femoris muscle).* ***(Middle)*** *Sagittal panoramic scan is seen from the lower iliac bone to below the ischial tuberosity. The greater sciatic foramen is demonstrated in this scan. The piriformis and sciatic nerve exit the pelvis via this foramen and run inferolaterally, the former to insert on the greater tuberosity and the latter inferiorly to supply the leg.* ***(Bottom)*** *Sagittal view shows the greater sciatic foramen using the ischial tuberosity as a landmark. The sciatic nerve and its relationship with the small external rotators of the hip is shown here. The sciatic nerve emerges between the piriformis and superior gemellus muscles after exiting the pelvis through the greater sciatic foramen.*

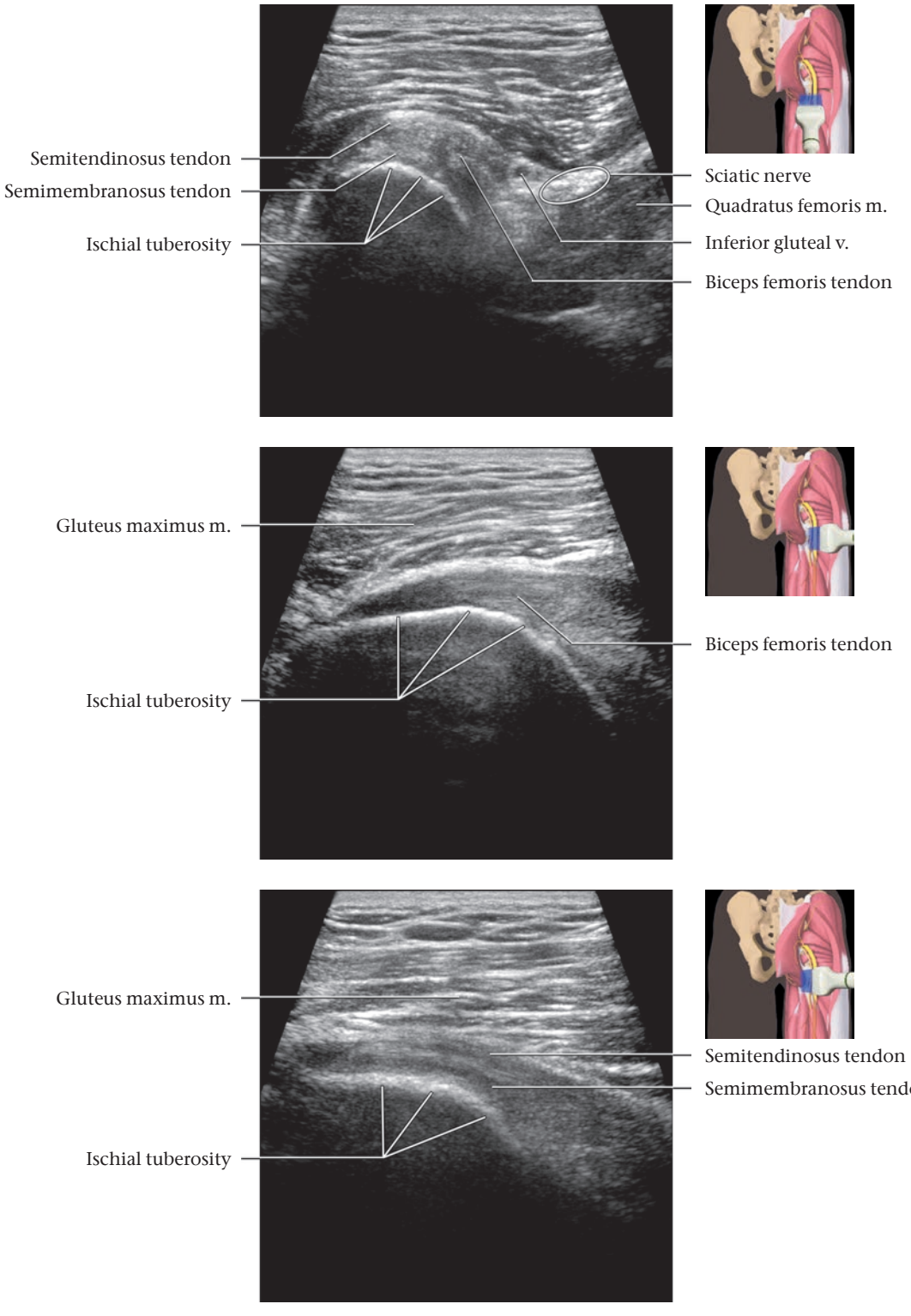
GLUTEAL MUSCLES

TRANSVERSE ISCHIAL

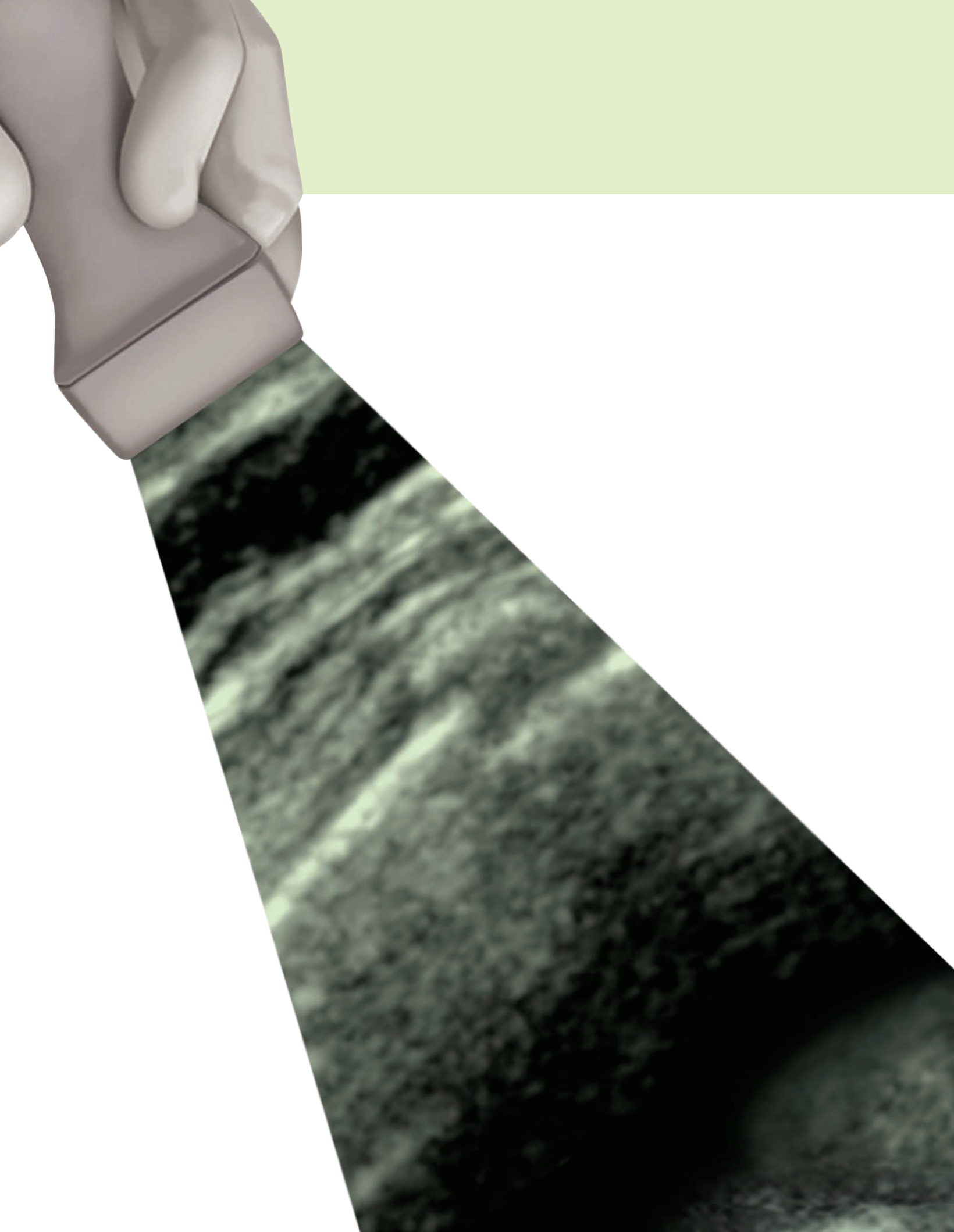


(Top) *Series of 3 transverse scans show the inferomedial aspect of the gluteal region. This image shows the obturator internus tendon exiting the lesser sciatic foramen, running laterally toward the lower aspect of the hip joint. The sciatic nerve runs superficial to this tendon.* ***(Middle)*** *Slightly inferiorly, this image shows the inferior gemellus muscle arising from the ischial tuberosity, running laterally over the neck of the femur and inserting at the piriformis fossa on the medial surface of the greater trochanter. The sciatic nerve runs superficial to this muscle.* ***(Bottom)*** *Further inferiorly, this image shows the quadratus femoris muscle arising from the lateral border of the ischial tuberosity and running laterally to insert on the quadrate tubercle of the femur. The sciatic nerve also runs superficial to this tendon.*

ISCHIAL TUBEROSITY



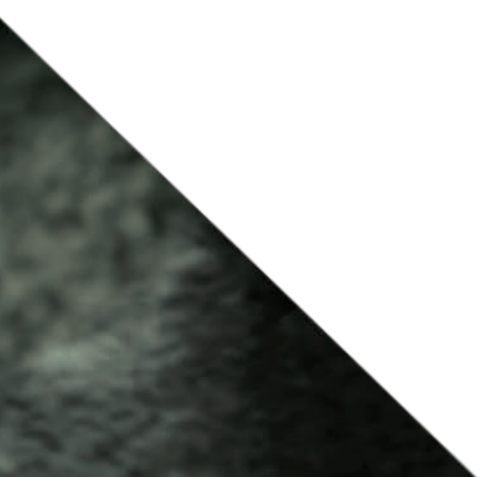
(Top) *Transverse scan shows the ischial tuberosity. The biceps femoris tendon originates lateral to the semimembranosus and semitendinosus tendons. The sciatic nerve and inferior gluteal vessels run just lateral to the ischial tuberosity. Inflammation in this region (e.g., ischiogluteal bursitis) may cause irritation of the sciatic nerve. More importantly, aspiration or injection to treat ischiogluteal bursitis should be performed with image guidance to avoid damaging the sciatic nerve.* ***(Middle)*** *Sagittal scan of the lateral aspect of the ischial tuberosity shows the origin of the biceps femoris tendon.* ***(Bottom)*** *Sagittal scan more medially on the ischial tuberosity shows the insertion of the semitendinosus and semimembranosus tendons. The semitendinosus muscle originates and runs for most of its course on dorsal surface of the semimembranosus tendon.*



SECTION 1

Introduction and Overview

Approach to Musculoskeletal Sonography **II**-1-2
Musculoskeletal Artifacts **II**-1-6



Ultrasound Machine

To perform musculoskeletal ultrasound, you first need access to an ultrasound machine equipped with a high-resolution transducer. Second, you need to understand, at least, the very basics of ultrasound technology. High-resolution transducers range from 10-22 MHz and are ideal for examining the superficial soft tissues. Similar to MR and increasing field strength, the relationship between increasing ultrasound transducer frequency and resolution is not necessarily linear. Most musculoskeletal ultrasounds can be performed with a linear transducer in the 10-12 MHz range. Moving from 12 MHz to 17 MHz will improve resolution to a mild degree but usually does not significantly alter diagnostic capability. In other words, if you have access to one high-frequency transducer, this is usually sufficient to begin musculoskeletal ultrasound. A disadvantage of high-resolution transducers is limited depth penetration; for deeper areas (gluteal region, proximal thigh) and large masses, a lower frequency transducer, such as a 5 MHz or 7.5 MHz transducer, is needed. The transducer is a delicate (and expensive) piece of equipment and must be handled with care. The transducer contains an interlinked array of piezoelectric crystals. These crystals are the bedrock of ultrasound technology. They convert an electrical signal into an ultrasound wave and vice versa. The same array of piezoelectric crystals emits and receives the ultrasound signal. One can imagine the transducer calling out into tissues and then listening for a returning sound or echo. This "calling and listening" happens many thousands of times a second (pulse repetition frequency). To improve transmission of sound waves, ultrasound gel is applied between skin and the transducer. Sound waves are transmitted from the transducer through ultrasound gel to the skin and deeper tissues. The ability of tissues to transmit sound waves is known as acoustic impedance. At tissue interfaces where there is a large difference in acoustic impedance, most sound waves are reflected back to the transducer, producing a bright echo. At interfaces where there is a little or no difference in acoustic impedance, most sound waves will be transmitted and not reflected back to the transducer, producing a dark echo. As expected, most sound waves that contact an interface parallel to the transducer face will be reflected back to the transducer. Sound waves impacting an irregular surface will be retracted away from the transducer (refraction). Sound wave attenuation also results from acoustic absorption, which is greater in tissues of higher viscosity.

Getting Started

The only way to learn musculoskeletal imaging is to get started. You need to do at least 80 shoulder ultrasound examinations to become comfortable with the technique. Those who do a lot of ultrasound are prone to develop musculoskeletal problems themselves, so be conscious of working posture, etc., at the outset. Ensure that both you and the patient are in a comfortable position to examine the area of interest. Try to warm the ultrasound gel using a dedicated ultrasound gel warmer, especially if examining the chest or abdomen. Hold the transducer between the thumb and finger. You should have either your little finger or the hypothenar eminence in contact with the patient's skin. This helps to anchor the transducer and ensure sufficient but not excessive transducer pressure on the skin. When assessing superficial structures, and especially when assessing color flow in superficial tissues, one should actively almost lift the transducer from the skin using plenty of intervening ultrasound gel to avoid distorting the tissues or effacing the vascularity. Develop a systematic examination procedure for each joint or region that includes all critical anatomical structures. Start your examination at the most symptomatic area and at least include the immediate surrounding area in your examination. For time efficiency, it is not necessary to complete the whole joint examination in every patient. For example, if the patient has medial ankle pain, concentrate on examining the medial and ankle joint proper; there is little to be gained from routinely examining the lateral or posterior ankle structures if there are no symptoms related to these areas. In children, a full examination may not be possible before the child becomes restless, so again concentrate on the most critical area. Sedation is not usually necessary or beneficial in children.

Machine Setup and Scanning

Understanding proper ultrasound machine setup is crucial to conducting high-quality ultrasound. This is similar to, say, tuning a guitar. It is very important to optimize image quality before and during scanning. Often it is helpful to begin by examining the contralateral normal side, as this allows you to both familiarize yourself with normal ultrasound anatomy and also setup the machine properly for that body part. This initial setup will often need repeated readjustment throughout the ultrasound scan. It is better to take a few high-quality images than many suboptimal images. Orient the image so that the proximal end is on the left side of the image and the distal end is on the right. Make sure there is no shadowing artifact from too little gel at the sides of the image, adjust the depth to include the relevant area only, zoom within reason to the target tissues, and adjust the focal zone and ultrasound gain to optimize image quality. During scanning, tissues can be compressed by the transducer to broadly gauge their stiffness. This dynamic capability of ultrasound is also helpful when differentiating between fluid and soft tissue in suspected abscess or hematoma, or between synovial proliferation and effusion. The dynamic capability of ultrasound is also helpful when assessing tendon tears, tendon subluxation, or shoulder impingement. Color or power Doppler is used routinely in the assessment of soft tissue inflammation, synovitis, and soft tissue masses. The relative sensitivity of color or power Doppler does vary from machine to machine. Color Doppler is flow-direction sensitive, whereas power Doppler is not flow-direction sensitive, though it is considered more sensitive overall to detecting slow flow and flow in small vessels.

Supplementary Imaging Techniques

With conventional ultrasound, the transducer emits and receives a sound pulse of a specific frequency at a single angle of insonation. The returning signal is of the same frequency, though weaker with the transducer "listening" specifically for that frequency. Several techniques over and above standard grayscale imaging may enhance image resolution, depiction, and interrogation. **Spatial compound ultrasound** amalgamates sonographic data from several different angles of insonation into a single image. By averaging image data from multiple angles

of insonation, spatial compound imaging improves definition of soft tissue planes, reduces speckle and other noise, and improves image detail. With **tissue harmonic imaging**, the transducer listens for not only returning signals of the transmitted frequency but also returning signals of harmonic frequencies (generated by passage of the sound wave though tissue) that are twice the transmitted frequency. Benefits of tissue harmonic imaging are most apparent in the midfield region, helping to improve tissue visibility and edge demarcation of soft tissue masses or tendon tears. **Extended field of view imaging** allows one to build up a panoramic image, which is helpful for measuring large masses, comparing tissue thickness or echogenicity in confluent areas, and perceiving the anatomical relationship of any abnormality.

Recognizing Pathology

Good quality musculoskeletal ultrasound is dependent on good understanding of musculoskeletal anatomy. You do not want your ultrasound technique to be hampered by trying to recall relevant anatomy. It is helpful to familiarize yourself with normal anatomy on the asymptomatic side before examining the symptomatic side. Be aware, however, of using the normal side as an internal reference of normality. Tendinosis and nerve entrapment, in particular, are often asymptomatic, and ultrasound often shows abnormal findings (to a comparable or lesser degree) on the asymptomatic normal side. Therefore, you need a good idea as to what the normal appearances are before proceeding to diagnose tendon or nerve pathology. Another prerequisite is knowledge of the likely pathologies in specific areas. Most musculoskeletal pathology is site specific. "You only find what you look for; you only look for what you know." Most tissues (tendons, nerves, ligaments) have the same appearance, irrespective of location. Also, tissue-specific pathology has a similar appearance, irrespective of location. For example, tendinosis, tendon tears, or tenosynovitis appear similar irrespective of location. Tendons, nerves, and ligaments are prone to anisotropy. This is the most common artifact you will encounter and can often be put to good use. To overcome this artifact, frequent transducer realignment to examine different areas of curved structures is necessary. For example, the anterior, mid, and posterior fibers of the supraspinatus as well medial and lateral aspects usually need to be assessed independently. For soft tissue masses, evaluate location, extent, internal structure, consistency, vascularity, relationship to adjacent critical structures, surrounding tissues, and regional nodes.

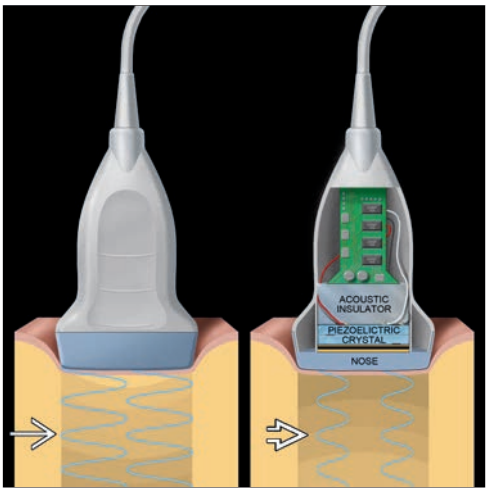
Clinical Implications

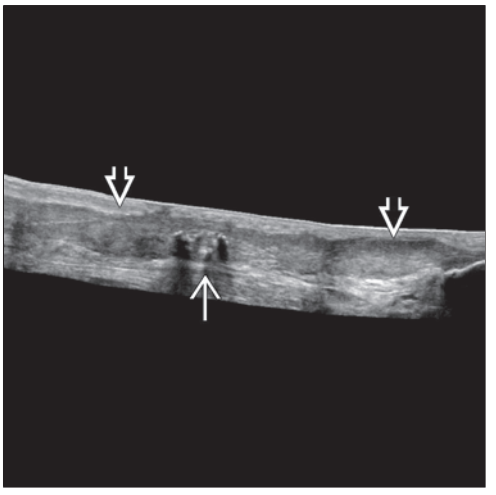
Ultrasound is the best first-line investigation for most soft tissue pathology. An explanation of patient symptoms can usually be obtained with ultrasound examination. Musculoskeletal ultrasound is most useful when symptoms are localized to a specific area, e.g., point tenderness. Ultrasound is much less useful when symptoms are not well localized, e.g., pain related to the whole knee or ankle joint. Try to grade every abnormality; there is little benefit in saying that there is supraspinatus tendinosis present. You need to know if this tendinosis is minimal, mild, moderate, or severe. Most superficial soft tissue masses can be accurately diagnosed with ultrasound. Ultrasound diagnosis is formulated not on a basis of one or two ultrasound signs but on the relative strength of multiple recognized ultrasound signs interpreted in conjunction with the clinical presentation. If the ultrasound findings are indeterminate, you can either follow-up with repeat ultrasound, proceed to an alternative investigation such as MR, or proceed to ultrasound-guided biopsy (or fine-needle aspiration for cytology). Similarly, if a satisfactory explanation for nontumoral symptoms is not found on ultrasound, it is usually best to proceed to further investigation, usually MR. There is little benefit to be gained from repeating the ultrasound examination. MR has particular advantages over ultrasound, and in these situations it is usually best to proceed directly to MR. MR is particularly useful for examining areas not accessible to ultrasound, e.g., intraarticular or intraosseous abnormalities. MR allows improved perception of large objects (particularly deep, ill-defined lesions and large tumors) and provides a clear anatomical surgical roadmap. MR allows a more reliable quantification of many structures (e.g., synovial volume) and is more sensitive in depicting soft tissue edema, as in myositis. Ultrasound should ideally precede MR for most soft tissue problems. MR examination, if necessary, can then be tailored to answer only those specific questions not answered by ultrasound. For example, there is no need to examine regional lymph nodes if ultrasound assessment has already been performed, nor is there a need to give intravenous contrast if tumor vascularity has always been determined by ultrasound.

Newer Ultrasound Techniques

3D ultrasound acquires volumetric ultrasound data, which can be reconstructed along any plane. This has been used to evaluate rotator cuff tears, soft tissues masses, and synovial proliferation. **Fusion imaging** allows real-time ultrasound imaging to be superimposed onto preloaded CT or MR imaging and viewed simultaneously on the ultrasound screen. Fusion imaging has been used in rheumatoid arthritis, bone biopsy, and sacroiliac joint injection. **Ultrasound elastography** measures and displays tissue elasticity and is divided into two types. **Strain elastography** involves gentle manual transducer compression of the tissues to measure relative tissue displacement (strain). This strain is displayed as a unitless color-coded map (elastogram) as strain is dimensionless. Stiff areas appear as low strain areas on elastograms. Operators may compare two regions of interest on elastograms to compute strain ratios. **Shear wave elastography** employs different physical principles and requires a specially modified transducer that produces high-intensity acoustic pulses (push pulses). These induce weak tissue displacements termed shear waves, whose velocities are then tracked by diagnostic impulses. Shear waves travel faster in stiff tissues. Shear wave elastograms have a quantitative output (m/sec or kilopascal). Elastography has been studied in tendons, muscles, and soft tissue masses and may be able to detect tendinosis before grayscale imaging. Although elastography seems promising, it requires standardization and precise identification of those areas where it can provide added value over standard grayscale imaging. **Microbubble-based ultrasound contrast imaging** significantly improves synovial vascularity detection, helping to grade severity of synovitis.

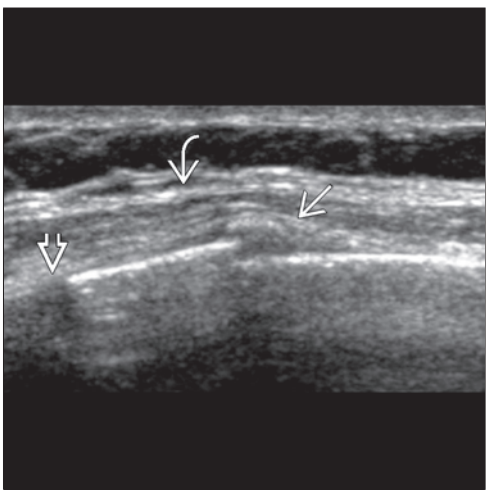
(Left) *Schematic shows an ultrasound transducer with and without external casing. An electrical impulse stimulates the piezoelectric crystal which emits a sound wave. The returning weaker sound wave of similar frequency is detected by the same crystal stimulating an electrical pulse.* ***(Right)*** *Extended field-of-view ultrasound shows an Achilles tendon following repair. Thickening of the whole tendon can be readily perceived. Thickening is a typical postoperative finding and can persist for years.*



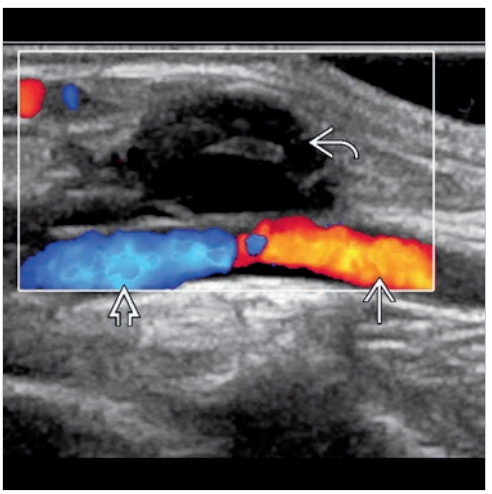


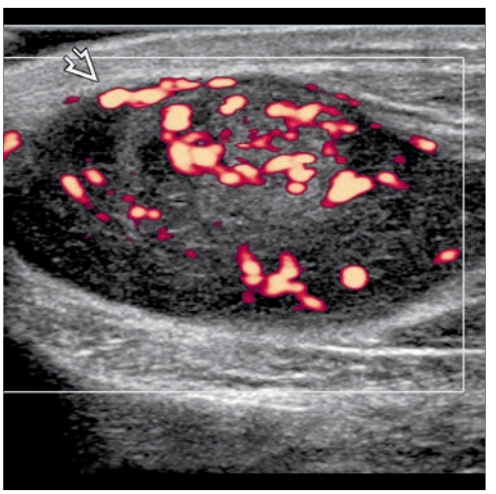
(Left) *Transverse standard grayscale ultrasound shows a healing rib fracture with callus.* ***(Right)*** *Transverse ultrasound with compound imaging shows early ossification of the callus more clearly than with standard ultrasound imaging. The demarcation between the rib and costal cartilage is also better appreciated on compound imaging, as are the soft tissue planes.*

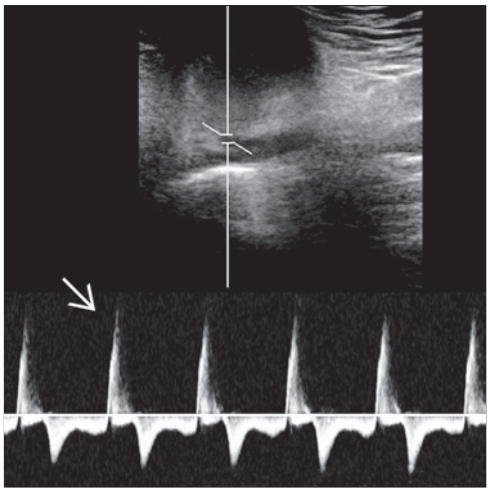


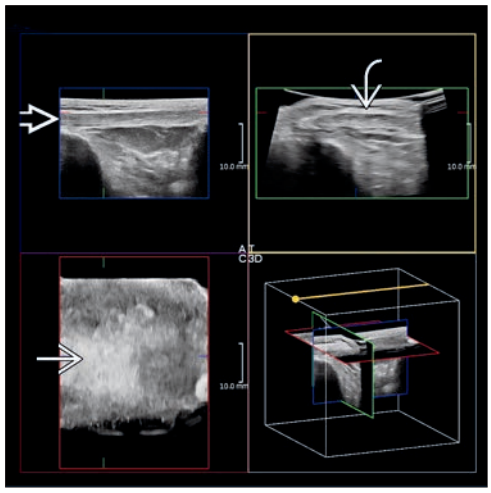


(Left) *Longitudinal color Doppler ultrasound shows the radial artery passing deep to a wrist ganglion. Arterial blood flowing towards the midpoint of the transducer head is colored red, while flow away from the midpoint of the transducer head is colored blue.* ***(Right)*** *Longitudinal power Doppler ultrasound shows characteristic irregular chaotic flow within a nerve sheath tumor of the medial nerve. No color direction is present on power Doppler imaging.*

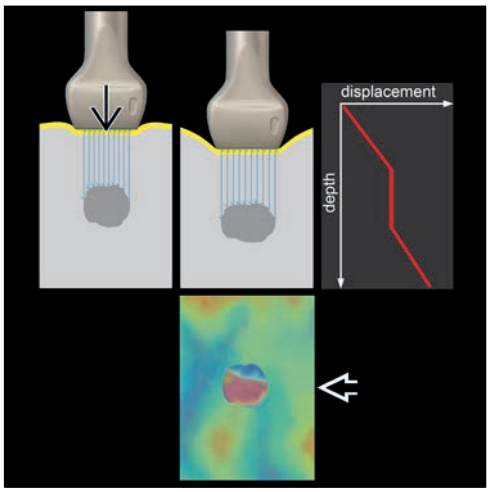


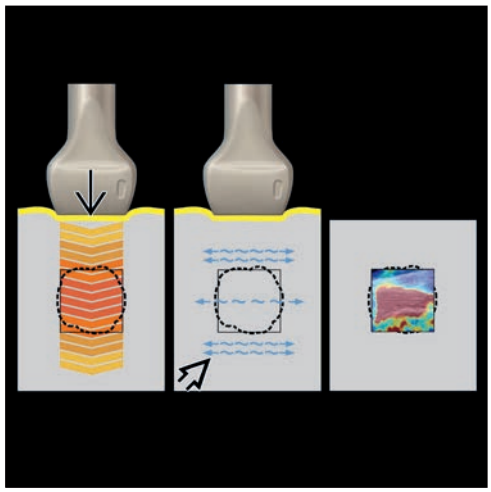




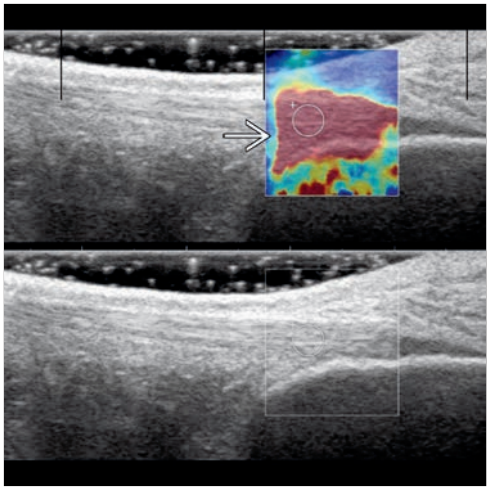


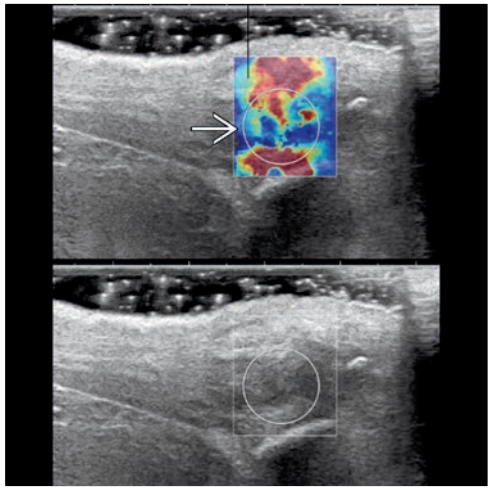
(Left) *Longitudinal pulsed Doppler ultrasound shows characteristic "to and fro"* ➔ *spectral waveform pattern at the neck of a femoral artery pseudoaneurysm.* ***(Right)*** *Longitudinal 3D ultrasound of the patellar tendon shows how longitudinal* ➔ *and transverse* ➔ *images can be reconstructed from the volumetric dataset acquired with a large, wide transducer placed on the patellar tendon. The coronal image* ➔ *is not useful in this case.*





(Left) *Strain elastography schematic shows probe pressure* ➔ *causing axial tissue displacement. Echoes during compression are used to measure relative displacement (strain)* ➔ *and displayed as color maps without units. Stiff tissue has relatively lower strain.* ***(Right)*** *Strain elastography schematic shows a modified probe sending push pulses* ➔ *into tissues, inducing shear waves* ➔ *that are tracked by diagnostic images. Color maps have quantitative units (m/sec or kilopascal). (Courtesy K. Bhatia, MD.)*





(Left) *Longitudinal shear elastography ultrasound shows a normal Achilles tendon. The tissue is mainly hard (expressed as red)* ➔ *with elasticity measured at 497 kilopascal.* ***(Right)*** *Longitudinal shear elastography ultrasound shows severe Achilles tendinosis. The tissue is more heterogeneous and soft (expressed as blue color)* ➔ *with elasticity measured at 133 kilopascal.*

MUSCULOSKELETAL ARTIFACTS

Definition

An ultrasound artifact is a feature seen on an image that is not representative of the tissue being scanned. These may be either technology or technique related and can take 1 of 4 forms.

- Feature seen on image does not exist
- Feature that should be seen on image is missing
- Feature is misplaced (misregistered) on image
- Feature seen is of incorrect brightness, shape, or size

Technological Aspects

Ultrasound technology works on some basic assumptions. These assumptions are not always correct and can lead to artifact formation. Not all ultrasound artifacts will be encountered in musculoskeletal ultrasound.

- Speed of sound propagation is same for all tissues (1,540 m/s)
- Ultrasound beam travels in a straight line
- Attenuation of sound is uniform
- All echoes detected by transducer have primarily arisen from transducer
- Time taken for an echo to return to transducer is directly related to distance of reflecting interface from transducer

Artifacts Due to Beam Characteristics

Anisotropy

Anisotropy is one of the most common artifacts encountered in musculoskeletal ultrasound. The term anisotropy refers to a property being directionally dependent, as opposed to isotropy, which implies identical properties in all directions. Anisotropy can result in a structure appearing hypoechoic if the ultrasound beam is not directly perpendicular to the structure. It is seen in tendons, ligaments, nerves, &, to a lesser degree, muscle due to their oblique course and parallel reflective surfaces. Anisotropy can occur when the ultrasound beam is angled as little as 5° off perpendicular. It can mimic pathology, such as tendinosis or tendon tear, or may make a biopsy needle less conspicuous. It is particularly noticeable when the structure being imaged is curving, e.g., the ankle tendons curving around the malleoli or the supraspinatus tendon fibers curving to their insertional area. Anisotropy is eliminated by angulating (toggling) the transducer head so that the ultrasound beam is aligned perpendicular to the area of interest. It is important to evaluate only the part of the structure that is perpendicular to the ultrasound beam & not be tempted to diagnose pathology in other adjacent parts. The anisotropic effect can frequently be used to more clearly demarcate a structure of interest such as the median nerve in the carpal tunnel or the ankle ligaments.

Off-Axis Lobe Artifact

Off-axis lobe artifact includes side lobe and grating lobe artifacts. Side lobes are multiple beams of low amplitude that project radially from the primary beam axis and are mainly seen with linear transducers. Grating lobes are additional off-axis beams that are stronger than side lobes. Both side and grating lobes are weaker than the primary lobe and, as such, do not normally give echoes of sufficient strength to be displayed. However, if a side lobe or a grating lobe encounters a more highly reflective structure outside the primary beam, their echoes may be incorrectly displayed on the image along the path of the main beam. Off-axis lobe artifacts in musculoskeletal imaging are usually seen as spurious echoes within an expected anechoic structure such as a cyst or an effusion. Much less commonly, off-lobe artifacts may give rise to multiple needle paths during ultrasound-guided intervention.

Beam Width Artifact

This artifact is due to incorrect positioning of the focal zone. A strong reflector located within the widened beam beyond the margin of the transducer will generate detectable echoes. These echoes are assumed to have originated from the narrow imaging plane of the primary beam and are displayed on the primary beam image even though they have not arisen with the primary beam area. Beam width artifact is typically seen either as spurious echoes displayed at the edges of an anechoic structure or as reduced contrast at the borders of a lesion. Although the distinction can be very difficult, beam width artifact produces a more confined artifact than off-axis lobe and, of course, can be improved by optimizing the focal zone. Off-lobe axis artifact will not improve with optimization of the focal zone.

Slice Thickness Artifact

Slice thickness artifact is similar to beam width artifact but instead of being predominantly in a medial-lateral direction, it occurs due to an aberration in the anteroposterior direction. Slice thickness artifact occurs due to the thickness of the beam, which is 90° to scan plane and equates to the thickness of the transducer head. The transducer will receive echoes from in front of and behind the assumed plane of origin, which will be included in the displayed image. Increasing the thickness of the transducer head will increase the propensity to develop slice thickness artifact.

Artifacts Due to Multiple Echoes

Reverberation Artifact

Multiple reflections (reverberations) can occur between any two strong reflectors parallel to each other or between the transducer and a strong parallel reflector. As a result of these strong reflectors, echoes are reflected back and forth repeatedly. This leads to spuriously reflected echoes being displayed beneath the real reflector at intervals equal to either the distance between the transducer and real reflector or the distance between the two strong reflectors. Each subsequent reflection is weaker than the previous one due to sound beam attenuation. Reverberation artifact in musculoskeletal imaging is most commonly seen when the ultrasound beam encounters a strongly reflecting surface, e.g., a biopsy needle or a metal prosthesis. An advantage of seeing this artifact is that it ensures your transducer is at a right angle to the structure being imaged. "Comet tail" artifacts are a particular type of reverberation artifact usually seen in echo-free regions and are composed of a dense tapering trail of echoes behind a highly reflective small structure such as calcification, crystal aggregate in gout, or colloid aggregate in a ganglion cyst.

Ring Down (Resonance) Artifact

Ring down (resonance) artifact is similar in its appearance to "comet tail" artifact but is generated by a different mechanism. When a transmitted ultrasound beam passes through small gas locules or fluid bubbles, the ultrasound energy leads to vibration of these bubbles,

which emit and return sound waves back to the transducer. The effect is a larger artifact than expected.

Mirror Image Artifact

Mirror image artifact occurs when an object is located directly in front of a highly reflective smooth surface. The ultrasound beam is totally reflected by the strong reflector back toward the object. When the beam hits the object, part of the energy is reflected back to the strong reflector, which then redirects this echo back toward the transducer. True and false images are created equidistant from but on opposite sides of the strong reflector. In musculoskeletal imaging, a mirror image artifact most commonly manifests as an extraosseous structure being mirrored within bone. The mirror image is inverted and, rather than being a exact copy, is often a distorted view of the real image.

Artifact Due to Velocity Errors

Velocity Error Artifact

The speed of sound varies within different tissues, though ultrasound technology assumes that all tissues have a constant speed of 1,540 m/sec. If the speed of sound through tissues is > 1,540 m/sec, the returning echo will return faster to the transducer leading to the structure being displayed more superficially on the image than expected. Conversely, if average speed through the tissues is < 1,540 m/sec, the structure will appear deeper than it is in reality. Sound travels ~ 10% slower through fat, which has a sound transmission speed of 1,450 m/sec, as opposed to lean tissue (1,540 m/sec).

Refraction Artifact

Refraction of the ultrasound beam at a boundary between two media of different acoustic impedance will result in image misregistration. In refraction artifact, a nonperpendicular incident ultrasound beam will refract and change direction at a boundary between two materials of different acoustic impedance. Since ultrasound display technology assumes that the sound beam travels in a straight line, it will misplace any returning refracted echoes to the side of the true object location. Refraction artifact may result in a structure appearing longer than expected or a misplaced duplication of a structure ("ghost image").

Defocusing Artifact (Edge Shadowing Artifact)

In defocusing artifact (edge shadowing artifact), refraction produces shadowing at the edges of a relatively large (compared to the ultrasound beam width) curved structure. Refraction occurs at the edge of the structure due to the curved edge and also differences in acoustic impedance between the two tissue types involved. The ultrasound beam at the edge of a structure, such as a cyst or soft tissue mass, is deviated from its original path. This is commonly seen in musculoskeletal imaging. Edge shadowing artifact is also the reason for shadowing seen commonly in full thickness Achilles tendon tear.

Artifact Due to Attenuation Error

Acoustic Shadowing Artifact (Posterior Acoustic Shadowing)

This is the most commonly encountered artifact in musculoskeletal ultrasound and is the reason why ultrasound, for example, cannot look deep into joints. Acoustic shadowing artifact is caused by severe attenuation of the ultrasound beam at an interface, either by reflection, absorption, or, less commonly, refraction, resulting in reduced sound being transmitted beyond that interface. This leads to an area of hypoechogenicity behind a strongly reflecting interface or strongly attenuating tissue. In musculoskeletal imaging, this is seen as shadowing posterior to calcification, bone, foreign bodies, or dense fibrous tissue. The main implication is that the tissues behind that structure are not visible on ultrasound. This can cause problems. For example, in examination of the knee, it may be difficult to tell whether or not a large osseous structure is attached to the bone. It is also an advantageous sign. For example, acoustic shadowing behind noncalcified tissue would make it very likely that this tissue is composed of dense fibrous tissue. Objects with a small radius or a rough surface are more inclined to produce a clean posterior shadow while objects with a large radius or smooth surface are more inclined to produce a dirty shadow as a result of reverberation echoes superimposed on the acoustic shadow.

Acoustic Enhancement Artifact (Increased Through-Transmission)

This is caused by low-attenuating structures such as fluid, resulting in no weakening of the ultrasound beam as it passes through these tissues relative to adjacent tissues. This leads to an area of high-amplitude echoes behind the area of low-attenuating tissue. This artifact is seen when examining fluid or low-attenuating tissue structures such as ganglion cysts, nerve sheath tumors, or giant cell tumor of tendon sheath. Tissues deep to the low-attenuation structure appear hyperechoic. Similar to acoustic shadowing, acoustic enhancement is a useful diagnostic sign and can be used, for example, to increase diagnostic accuracy of nerve sheath tumors that typically show mild to moderate acoustic enhancement.

Artifact Due to Improper Machine Setting

Range Ambiguity

Ultrasound technology assumes that each pulse of echoes is received by the transmitter before the next pulse is emitted. If returning first pulse echoes arrive after the second pulse has been transmitted, returning first pulse echoes are interpreted incorrectly as having originated from the second pulse and will be incorrectly placed nearer to the transducer. Range ambiguity artifact is not commonly seen now, as the ultrasound machine automatically reduces pulse repetition frequency during imaging of deeper structures.

Equipment-Generated Artifact

Incorrect use of equipment controls such as gain or time-gain compensation can result in the visualized echoes being either too bright or too dark. To avoid these artifacts, the machine should be properly setup at the start of each examination and repeatedly readjusted during the course of the examination.

Artifact Seen During Doppler Imaging

Transducer Pressure

Too much transducer pressure may obliterate vascular flow, particularly in soft superficial vascular structures. To avoid this happening, you should use a large amount of ultrasound gel and actively lift the transducer off the skin when assessing tissue vascularity. Noticing the effect of transducer pressure can be helpful for

tissue characterization. For example, the vascularity of nerve sheath tumors typically blanches with only slight transducer pressure.

Noise Artifact

Noise is caused by increased color or power Doppler settings. Noise can be recognized as small, spurious, inconsistent color dots. Color gain settings should be adjusted to minimize noise. To achieve maximum color sensitivity, increase color gain until noise pixels are clearly seen in the Doppler box, then slowly decrease gain until nearly all of the noise has disappeared.

Aliasing Artifact

Aliasing artifact occurs when the velocity range exceeds the scale available to display and is only seen with color and spectral Doppler imaging. Aliasing is not seen with power Doppler, as it does not provide flow-directional information. The sample rate on color or pulsed Doppler is equal to the pulse repetition frequency, which limits maximum velocity scale. The Nyquist limit is the upper limit of Doppler shift that can be detected accurately and is equal to half the pulse repetition frequency. If Doppler shift signal is higher than the Nyquist limit, aliasing artifact occurs with inaccurate display of color or spectral Doppler velocity. In color Doppler, the display "wraps around" the scale and overwrites exiting data while in spectral Doppler, velocity peak is cut off at the top end of the scale and is displayed at the lower end of the scale, i.e., below baseline. Aliasing can be overcome by increasing the velocity scale (pulse repetition frequency). Increasing the pulse repetition frequency is disadvantageous in that low velocities cannot be accurately measured.

Range Ambiguity Artifact

As expected, range ambiguity artifact can occur in Doppler imaging with increasing pulse repetition frequency used to overcome aliasing artifact. This should be identified in order to avoid detection of frequency shifts deeper than the target object.

Directional Ambiguity/Indeterminate Flow Direction Artifact

This artifact leads to the spectral waveform being displayed with nearly equal amplitude above and below spectral analysis baseline in a mirror image pattern. It is caused by the ultrasound beam intercepting the vessel at a 90˚ angle, particularly for small vessels moving in and out of the imaging plane. True bidirectional flow is a rare occurrence and is only seen in the neck of a pseudoaneurysm or when there is reversed diastolic flow near a high-resistance vascular stenosis. True bidirectional flow is never simultaneously symmetrical above and below baseline and may be seen to vary across the cardiac cycle.

Improper Doppler Angle With No Flow Artifact

Since Doppler imaging is angle dependent, the angle formed between the interrogating sound beam and vascular flow should be optimized. The angle can be changed by electronic steering. When the angle between the ultrasound beam and the vessel being studied approaches 90˚, no Doppler shift is detected and color may not present even though flow is present. The color box should be steered to make the insonation angle to flow closer to 0˚ or 180˚ and not close to 90˚. This Doppler angle effect artifact is seen in color, power, and spectral Doppler imaging. The ideal Doppler imaging angle is either 0˚ or 180˚ but is generally not anatomically achievable when imaging vasculature. A Doppler angle of 60˚ has traditionally being specified as a "standard" though with improvements in ultrasound technology, a better criterion would be an angle of 45-55˚, striving to measure velocities at 50˚ whenever possible.

Blooming Artifact ("Color Bleed")

This artifact is usually caused by abnormally high Doppler gain settings leading to color signal extending beyond the true grayscale vessel margin. It leads to color display outside a vessel wall, making vessels appear larger, and also potentially masking luminal detail, such as the presence of a thrombus. Decreasing color Doppler gain will minimize blooming artifact, though it will also reduce sensitivity to flow detection in small vessels.

Flash Artifact

Movement of either the patient or the transducer during Doppler imaging gives rise to a random color mosaic that obscures the grayscale image. Power Doppler is most susceptible to this artifact.

Mirror (or Ghost) Image Artifact

This is caused by the same mechanism as that seen with grayscale imaging and is a feature of color, spectral, or power Doppler imaging. It most commonly occurs adjacent to highly reflective surfaces such as the lung when, for example, imaging the supraclavicular region where one may see duplication of the subclavian artery or vein with the false images being displayed deeper than the real image.

Pseudoflow Artifact

The presence of fluid flow in nonvascular cystic collections can mimic real blood flow in color or power Doppler imaging. However, no arterial or venous spectral waveform will be seen if this apparent fluid flow is subjected to spectral Doppler analysis.

Twinkling Artifact

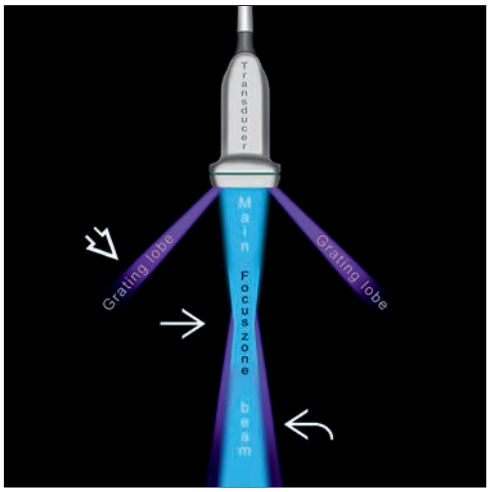
Twinkling artifact can be seen behind any strongly reflecting surface such as calcification, bone, or foreign body. It is seen as a mosaic of rapidly changing colors, mimicking turbulent flow, and present deep to the strongly reflecting surface, such as a calcified nodule, on both color and power Doppler. It is most likely caused by narrow bandwidth noise induced by "phase jitter" in the Doppler circuitry of the ultrasound system.

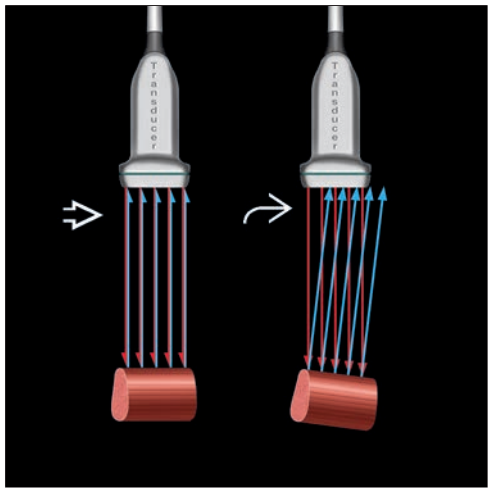
Edge Artifact

Occurs at the margin of a strong, smooth reflector (such as a calcified mass or cortical bone), resulting in persistent color along the rim of a strong reflector. Spectral analysis in this case will show no vascular flow pattern. Edge artifact is seen more commonly with power Doppler than color Doppler imaging.

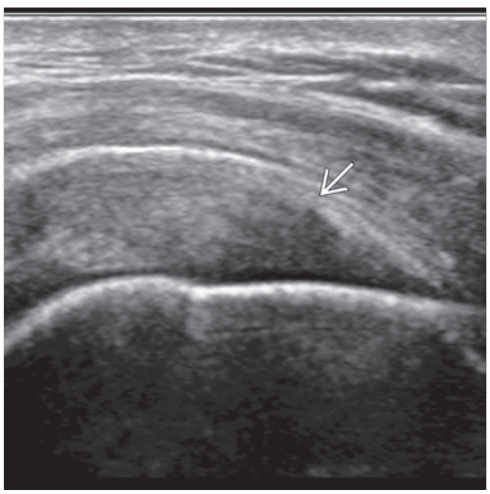
Motion Artifact

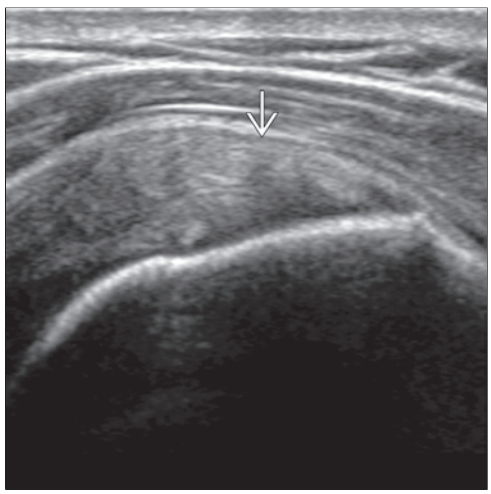
Even a small amount of motion will give rise to noise on color or power Doppler imaging. Noise appears as random dot-like flashes on color or power Doppler imaging. It is caused by low-frequency Doppler shifts and can be minimized by high-pass wall filters, though these filters will reduce sensitivity to detect slow-flowing blood. Very slow-flowing blood is best detected on grayscale imaging alone when moving red cell aggregates will be seen as slow-moving intravascular echoes.



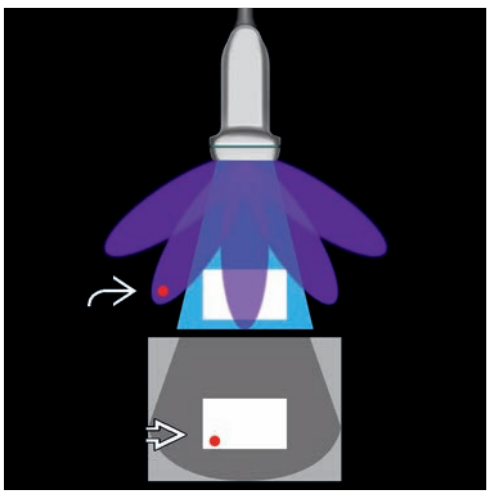


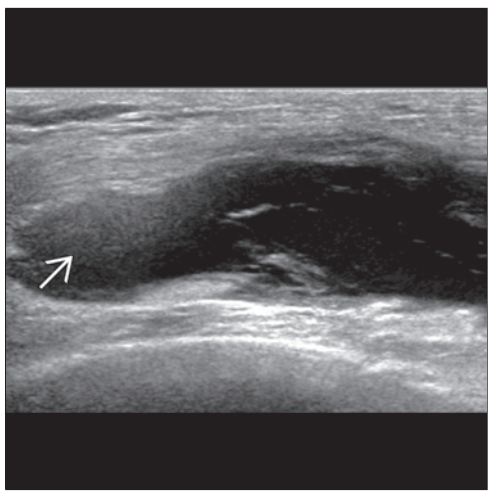
(Left) *Schematic of an ultrasound beam shows the primary (main) beam narrowing at the focal zone and then diverging. Grating lobes and slide lobes are both off-axis lobes.* ***(Right)*** *Schematic shows anisotropy effect. If the structure scanned is parallel to the transducer, all of the reflected echoes can be detected. When the structure is not parallel to the transducer, only some or none of the reflected echoes will be detected, leading to the structure becoming hypoechoic.*





(Left) *Longitudinal ultrasound shows moderate hypoechogenicity of the distal fibers of the supraspinatus tendon, which could simulate a tendon tear.* ***(Right)*** *Longitudinal ultrasound of same tendon following angulation of the transducer so that the fibers lie more parallel to the transducer head shows reduction in hypoechoic anisotropic effect. No tear is present.*

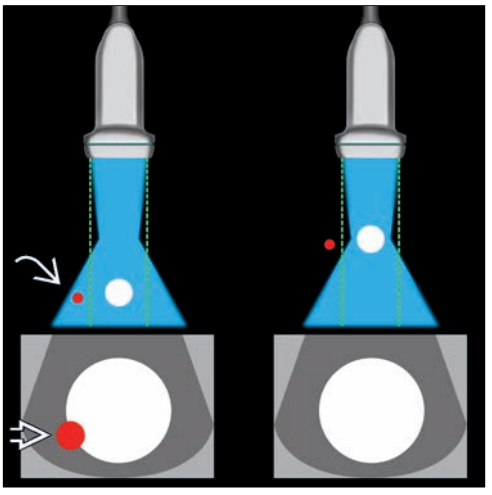


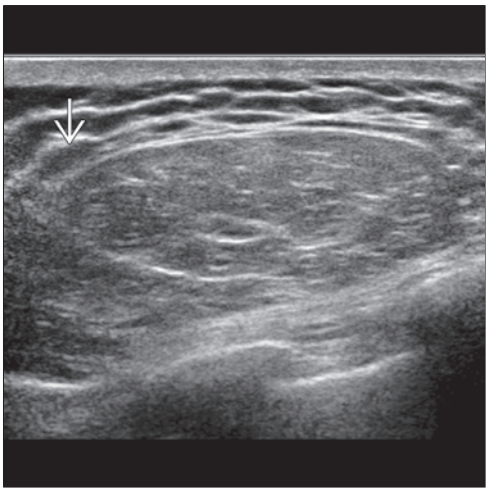


(Left) *Schematic shows beam width artifact. The purple beams represent multiple side lobes, which encounter an object (red dot). The display, assuming that all returning echoes came from the main beam, will misplace and duplicate the structure as shown.* ***(Right)*** *Transverse ultrasound shows off-axis lobe artifact resulting in spurious echoes from subcutaneous fat appearing in knee joint effusion. This is commonly seen at the edges of cystic structures and can simulate fluid debris.*

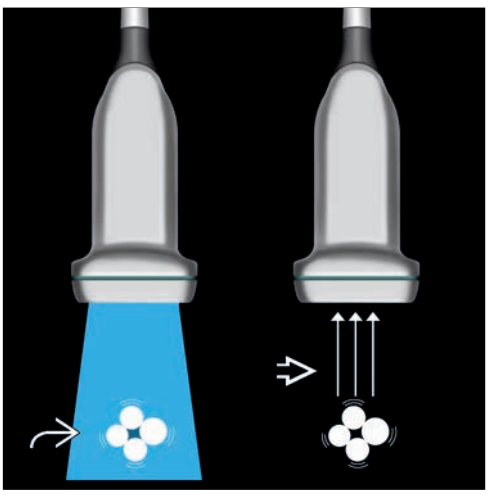
MUSCULOSKELETAL ARTIFACTS

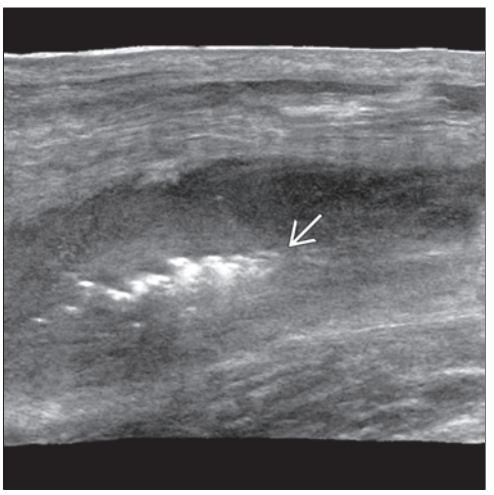
(Left) *Schematic shows beam width artifact. The blue beams represent multiple side lobes, which encounter an object (red dot)* ⇄*. The display, assuming that all returning echoes came from the main beam, will misplace and duplicate the structure as shown* ⇄*.* ***(Right)*** *Transverse ultrasound shows blurring of the lateral margin of a lipoma and adjacent tissue* ⇄ *due to either beam width or off-axis lobe artifact. Optimization of the focal zone will help reduce the former but not the latter artifact.*



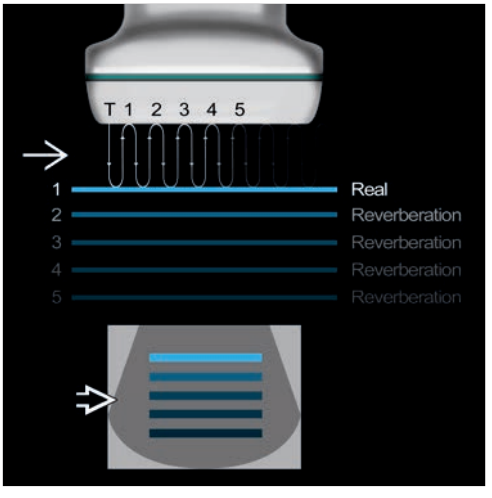


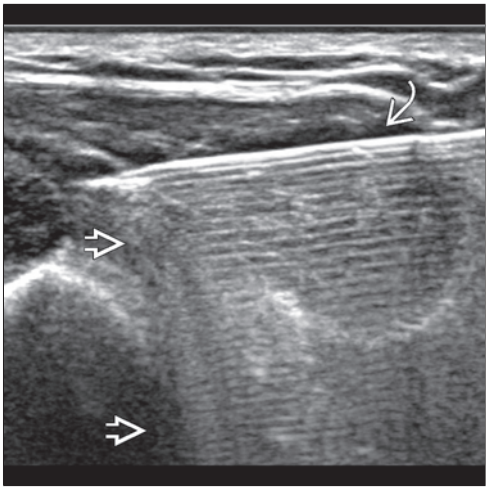
(Left) *Schematic shows ring down artifact. If the main beam encounters air bubbles, it can induce vibrations in these bubbles* ⇄*, causing a continuous source of sound energy transmitted back to the transducer* ⇄*. Therefore, the artifact appears larger than expected.* ***(Right)*** *Longitudinal ultrasound shows increased echogenicity of gas bubbles* ⇄ *due to ring down artifact within hypoechoic granulation tissues as a result of low-grade soft tissue infection.*

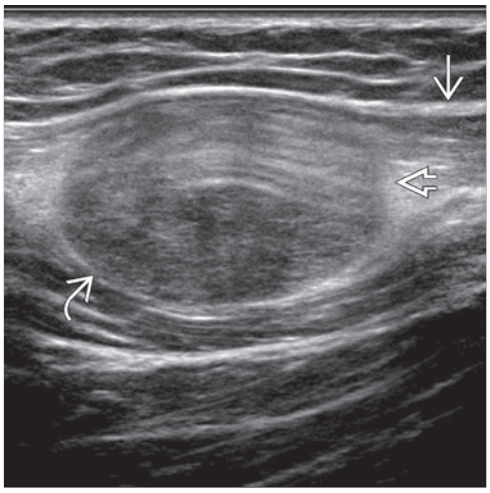


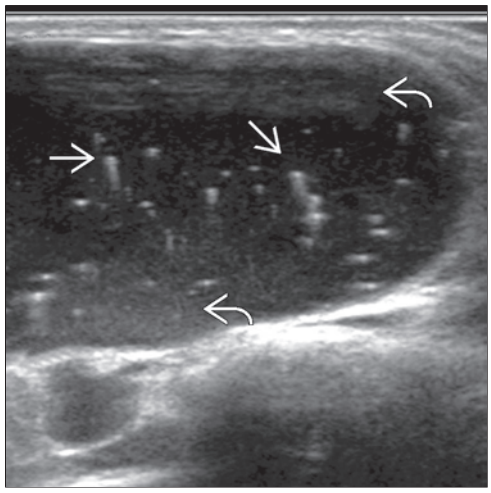


(Left) *Schematic shows reverberation artifact. Repeated reflections* ⇄ *between the transducer face and a very strong reflector causes progressively diminishing reverberations* ⇄ *to occur deep to the real echoes. This artifact can also occur between 2 strongly reflecting surfaces.* ***(Right)*** *Longitudinal ultrasound shows reverberations* ⇄ *deep to the strongly reflecting biopsy needle* ⇄*. This artifact occurs from reverberation between the outer coaxial needle and the inner biopsy needle.*

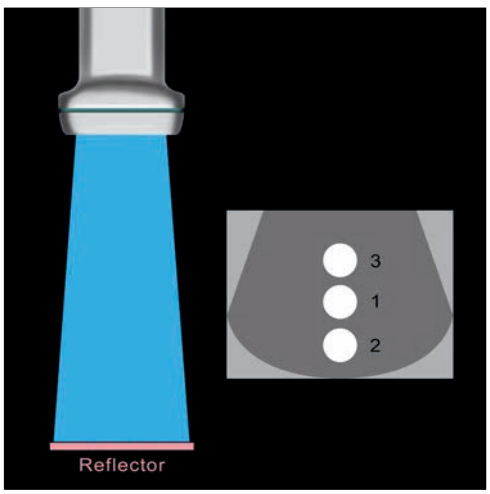


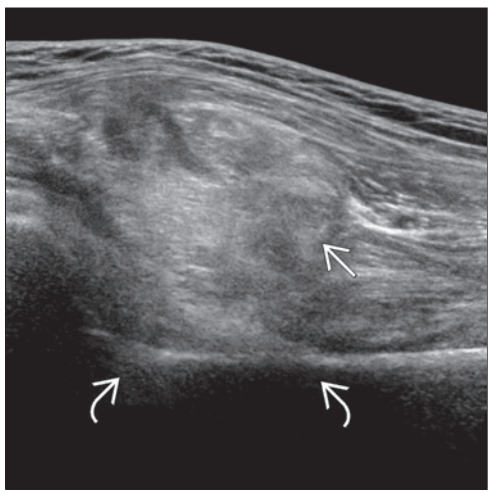




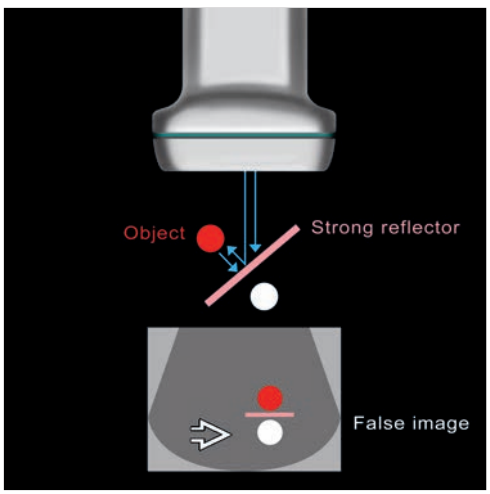


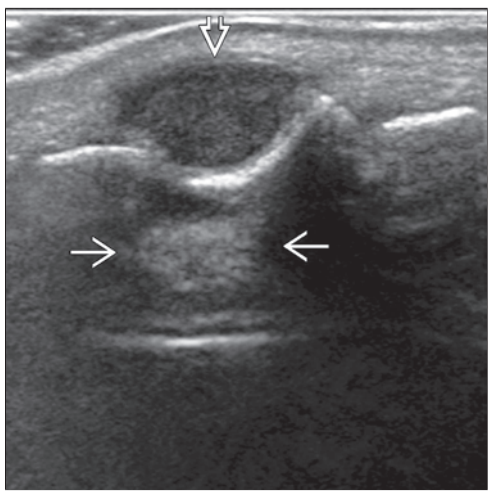
(Left) *Longitudinal ultrasound shows linear echoes within a nerve sheath tumor due to reverberations from an overlying strongly reflective investing fascia.* ***(Right)*** *Transverse ultrasound of ganglion cyst shows "comet tail" artifacts due to colloid aggregates within the mucopolysaccharide fluid content. There is also some slice thickness artifact simulating echogenic fluid content on this image.*





(Left) *Schematic shows propagation speed artifact. The reflector is in position 1. If the actual propagation speed is more than expected, the reflector will appear in position 3. If the actual propagation speed is less than assumed, the reflector will appear in position 2.* ***(Right)*** *Longitudinal ultrasound of the thigh shows ill definition of the proximal femur cortex due to propagation speed artifact from intramuscular soft tissue sarcoma on the anterolateral aspect of the thigh.*

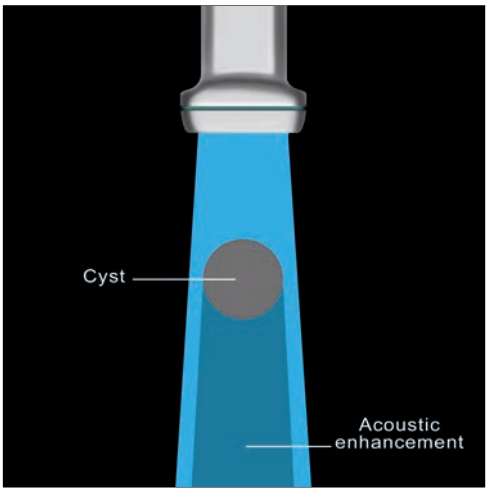


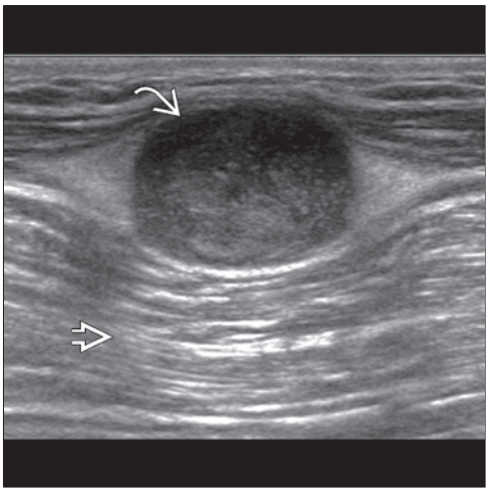


(Left) *Schematic shows mirror image artifact. Reflections from a strong reflector encounter another object and are reflected first back to the highly reflective surface before returning to the transducer. This produces an inverted mirror image of the object.* ***(Right)*** *Longitudinal ultrasound shows inverted, distorted, and incompletely portrayed mirror image artifact of a juxtacortical giant cell tumor due to strong cortical bone reflection.*

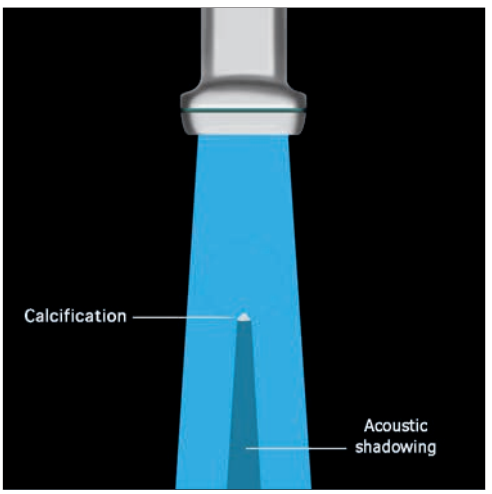
MUSCULOSKELETAL ARTIFACTS

(Left) *Schematic shows acoustic enhancement artifact posterior to a low-attenuating tumor (e.g., cyst, nerve sheath tumor, giant cell tumor, lipoma).* ***(Right)*** *Longitudinal ultrasound shows characteristic acoustic enhancement ⇨ posterior to a nerve sheath tumor ⇨ in the thigh.*



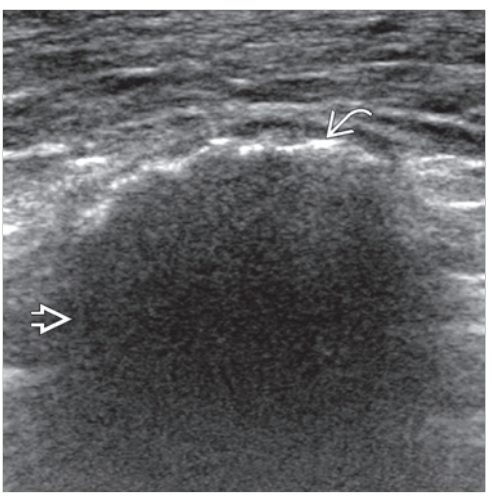


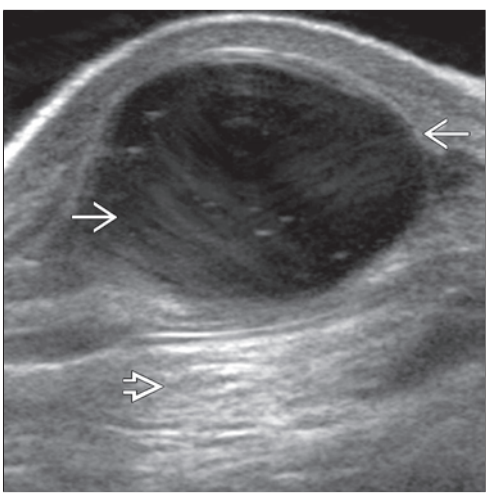
(Left) *Schematic shows acoustic shadowing artifact. A strong reflector such as a calcified nodule stops all through transmission, leading to posterior acoustic shadowing.* ***(Right)*** *Longitudinal ultrasound of the thigh shows acoustic shadowing ⇨ posterior to a small area of subcutaneous calcification ⇨.*

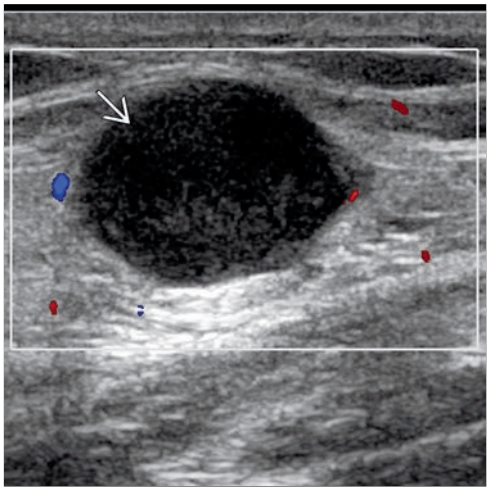


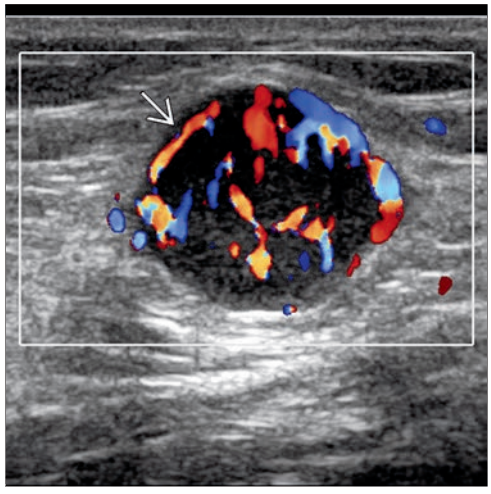


(Left) *Longitudinal ultrasound of the gluteal region shows dense acoustic shadowing ⇨ deep to the surface of a heavily calcified granuloma ⇨.* ***(Right)*** *Transverse ultrasound shows range ambiguity artifact ⇨ with alternating echogenic bands at the sides of a cystic structure due to soft tissue echoes returning from deeper tissues. Increased through transmission ⇨ mainly in the central part of the cyst is seen.*

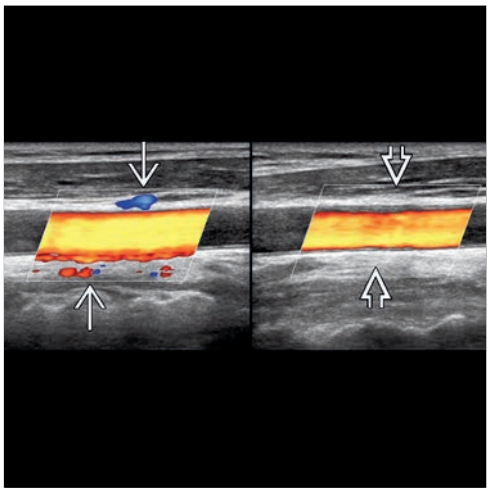


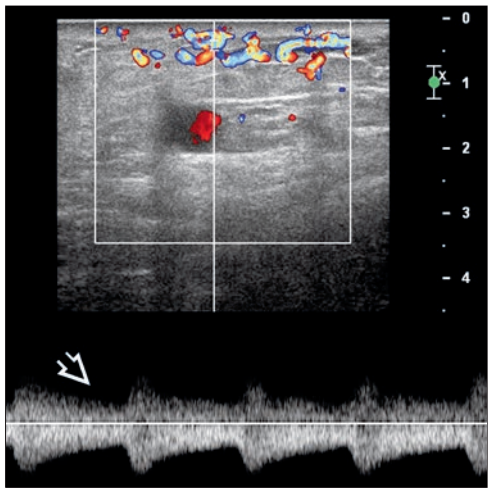




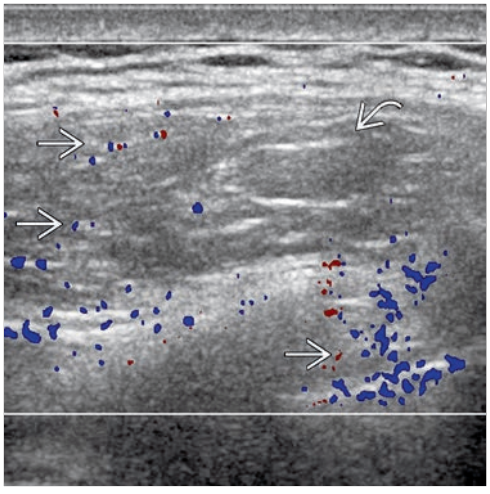


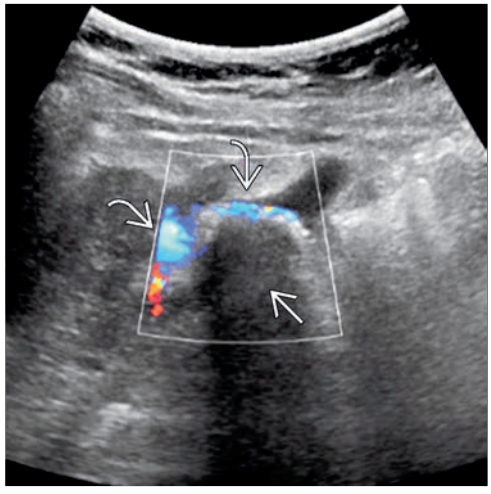
(Left) *Longitudinal color Doppler ultrasound shows a subcutaneous nerve sheath tumor with moderate transducer pressure. No intratumoral hyperemia is evident* ➔. ***(Right)*** *Longitudinal ultrasound of same tumor with minimal transducer pressure now shows moderate intratumoral hyperemia* ➔. *Transducer pressure should be kept to a minimum, especially when assessing vascularity of superficial structures.*



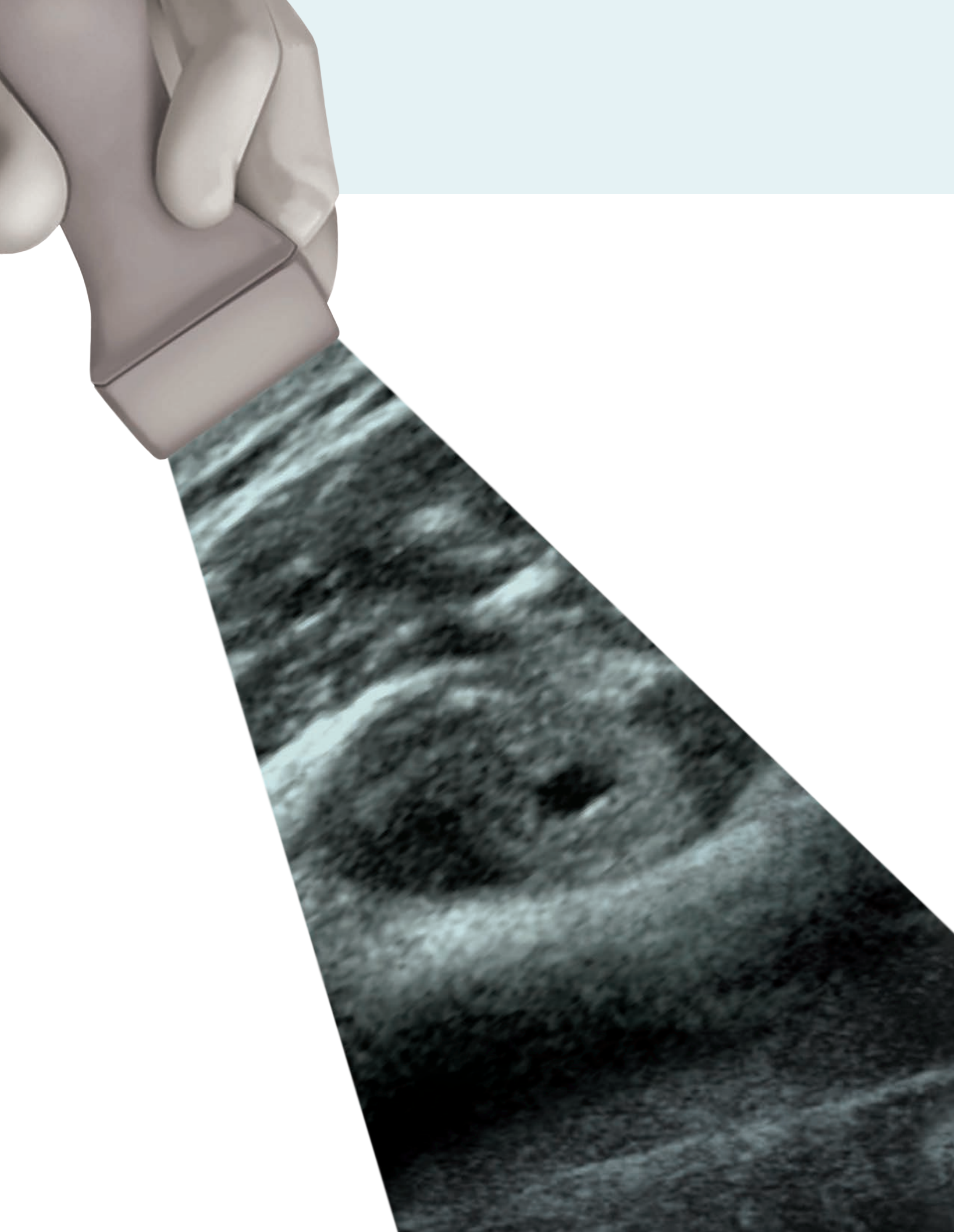


(Left) *Longitudinal color Doppler ultrasound shows blooming artifact on the left side* ➔ *("color bleed"). After lowering the color Doppler gain settings, the blooming artifact disappears as seen in the right-sided image* ➔. ***(Right)*** *Longitudinal color Doppler spectral ultrasound of a venous vascular malformation shows directional ambiguity artifact* ➔ *in which the waveform is displayed with nearly equal amplitude above and below the baseline in a mirror image pattern.*





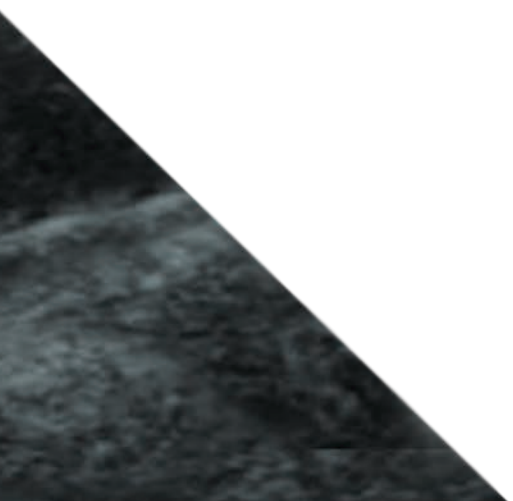
(Left) *Transverse color Doppler ultrasound of a subcutaneous lipoma* ➔ *shows noise artifact* ➔ *as a result of too high color Doppler gain setting. When the gain was turned down, no increased "vascularity" was present.* ***(Right)*** *Transverse color Doppler ultrasound shows Doppler edge artifact with persistent color* ➔ *signal around the the rim of the strong reflector* ➔ *(calcified structure).*



SECTION 2

Tendon Disorders

Rotator Cuff/Biceps Tendinosis **II**-2-2
Rotator Cuff/Biceps Tendon Tear **II**-2-14
Non-Rotator Cuff Tendinosis **II**-2-22
Non-Rotator Cuff Tendon Tears **II**-2-32
Tenosynovitis **II**-2-44
Elbow Epicondylitis **II**-2-54



ROTATOR CUFF/BICEPS TENDINOSIS

Key Facts

Terminology

- Collagenous degeneration of rotator cuff ± biceps tendons with proteoglycan deposition

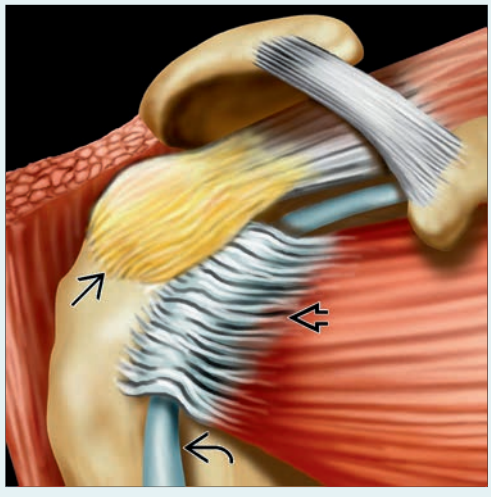
Imaging

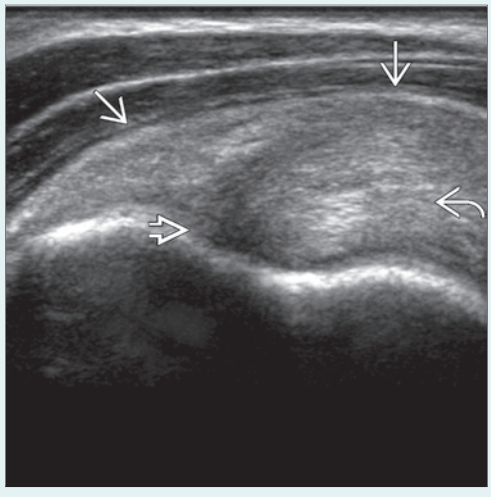
- Supraspinatus > infraspinatus > biceps > subscapularis
- Diffusely thickened tendon with diffuse hypoechogenicity and indistinct fibrillar pattern
  - Graded as mild, moderate, or severe
- Cortical irregularity of tendon insertional area
- Biceps tendinosis usually accompanies rotator cuff tendinosis
  - Proximal end of bicipital groove is most common site of biceps tendinosis
- Strong association between degree of tendinosis and tendon tears
  - Focal hypoechoic areas of proteoglycan accumulation can be difficult to distinguish from intrasubstance tears
  - Tears are more linear, more hypoechoic, and sharper in outline, may or may not be associated with volume loss of tendon contour
- Subclinical tendinosis of similar severity often present on opposite side
- Ultrasound is better than MR for assessing tendinosis as tendon detail such as fibrillar pattern is better appreciated
- Calcific tendinosis: Formative, resting, and resorptive phases
  - Focal echogenic mass within rotator cuff tendon with acoustic shadowing

Top Differential Diagnoses

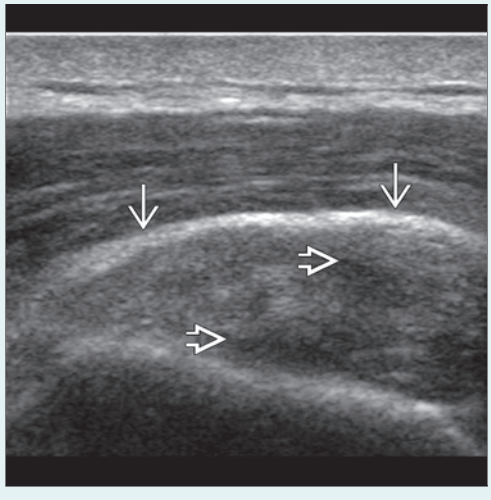
- Intrasubstance tendon tears
- Anisotropic effect

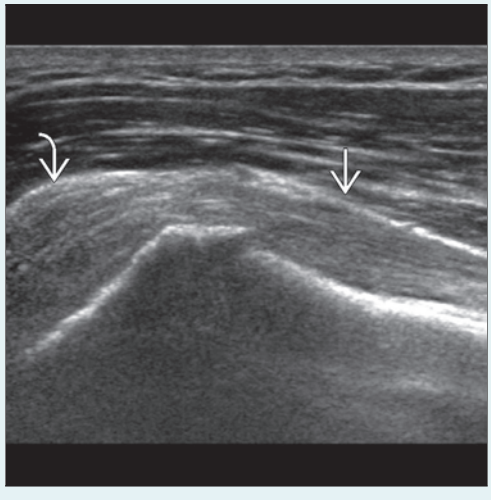
(Left) *Oblique graphic shows a diffusely thickened supraspinatus tendon indicative of tendinosis. A normal subscapularis tendon and biceps tendon are also shown.* ***(Right)*** *Longitudinal ultrasound shows a diffusely thickened and hypoechoic supraspinatus tendon indicative of moderate to severe tendinosis. There is still some preservation of the fibrillary pattern in most areas of the tendon. Note the hypoechoic area close to the insertion due to anisotropy.*





(Left) *Longitudinal ultrasound shows a diffusely thickened and hypoechoic infraspinatus tendon. Multiple poorly demarcated, hypoechoic areas with loss of distinct fibrillary structure are present. Features are indicative of severe infraspinatus tendinosis.* ***(Right)*** *Longitudinal ultrasound shows moderate tendinosis of the long head of biceps tendon. The tendon just proximal to the bicipital groove is more severely swollen. This is the most common site of tendinosis and tear of the biceps tendon.*





ROTATOR CUFF/BICEPS TENDINOSIS

TERMINOLOGY

Synonyms
- Rotator cuff tendinopathy

Definitions
- Collagenous degeneration of rotator cuff ± biceps tendons with proteoglycan deposition

IMAGING

General Features
- Best diagnostic clue
  - Diffusely thickened tendon with diffuse hypoechogenicity and indistinct fibrillar pattern
- Location
  - Supraspinatus > infraspinatus > biceps > subscapularis tendon
  - Slight preponderance in dominant shoulder
- Morphology
  - Thickened, inhomogeneous tendon ± surface fraying
    - Tendon torn or partially torn in advanced cases with fluid entering defect
    - Strong association between degree of tendinosis and presence of tendon tears

Radiographic Findings
- Radiography
  - Flat-undersurface acromion, anteriorly hooked acromion, anterior or lateral downsloping acromion, os acromiale
  - Acromio-clavicular joint osteophytes, acromial spurs
  - Surface irregularity, sclerosis, or subcortical cysts of greater tuberosity
  - Tendon calcification in calcific tendinosis

MR Findings
- T1WI
  - Thickened tendon with intermediate signal intensity
- T2WI
  - Increased signal intensity of tendon on PD FSE, FS PD FSE, STIR & T2* GRE

Ultrasonographic Findings
- Thickened, hypoechoic tendon with patchy and linear areas of more pronounced hypoechogenicity
  - Graded as mild, moderate, or severe based on degree of thickening, hypoechogenicity, and loss of normal fibrillar pattern
    - Measurement of tendon thickness is generally not helpful as there are no distinct landmarks and thickness is dependent on patient size
  - Focal hypoechoic areas of proteoglycan deposition can be difficult to be distinguished from intrasubstance tears
    - Tears are more linear, more hypoechoic, and sharper in outline, may or may not be associated with changes in surface contour
  - Noninstrasubstance tears are discernible through changes in tendon contour (contour flattening, retraction, fluid gap)
- In severe tendinosis, tendon is severely thickened and diffusely hypoechoic
- Tendinosis generally affects all rotator cuff tendons to some degree with supraspinatus most affected
  - Occasionally, only 1 tendon primarily affected
  - Biceps tendinosis usually accompanies rotator cuff tendinosis
    - Normal biceps tendon has oblong cross-sectional contour at proximal end of bicipital groove, which is most common site of tendinosis
    - Biceps tendon becomes thickened, more rounded, and more indistinct with increasing severity of tendinosis
- Cortical irregularity of tendon insertional area occurs with more severe degrees of tendinosis
- Likelihood of tendon tear increases as degree of tendinosis increases
  - Areas where tendinosis occurs correlate closely with those areas where tears occur
  - Tears rarely happen in normal tendons
  - Likelihood of successful repair ↓ as severity of tendinosis ↑
- Tendon hyperemia may infrequently be seen and represents neovascularity but not true inflammation
  - Tendon hyperemia is much less common in rotator cuff tendons than in tendinosis at other sites
- Ultrasound allows ready comparison with opposite side
- Subclinical tendinosis of similar severity is often present on opposite asymptomatic side
  - Be careful about using opposite asymptomatic side as internal reference of normality
- **Calcific tendinosis**
  - Formative, resting, and resorptive phases
    - Focal echogenic mass within rotator cuff tendon with acoustic shadowing
      - Variable size and multiplicity
      - During formative and resorptive stages, calcification can be less echogenic with less acoustic shadowing

Imaging Recommendations
- Best imaging tool
  - Ultrasound is better than MR for assessing tendinosis as tendon detail, such as fibrillar pattern, can be better appreciated
    - Patients tend to prefer ultrasound
- Protocol advice
  - Systematically examine tendons, taut and nontaut, in longitudinal and transverse planes, with patient in sitting position
  - Arm rotated into different positions to optimize visibility of each tendon in turn
    - Supraspinatus tendon: Arm extended and internally rotated (i.e., back of hand resting against nape of back [Crass position])
      - Alternatively, use hand in back pocket (modified Crass) or hand on iliac crest position
      - If too painful for patient, normal supraspinatus abnormalities are still apparent with hand in neutral position (hand on lap)
    - Infraspinatus and teres minor tendons: Arm abducted and internally rotated (i.e., with hand on opposite shoulder)
    - Subscapularis and long head of biceps tendons: External rotation of arm with elbow flexed
    - Confirm all abnormalities in 2 longitudinal and transverse planes
  - Always aim to grade severity of tendinosis

ROTATOR CUFF/BICEPS TENDINOSIS

DIFFERENTIAL DIAGNOSIS

Intrasubstance Tendon Tears
- Focal areas of proteoglycan deposition may mimic intrasubstance tears and vice versa
  - Tears are more hypoechoic, more sharply defined, and more linear, ± contour flattening or retraction of tendon

Anisotropic Effect
- Tendon appears artifactually hypoechoic when ultrasound beam is not perpendicular to tendon fibers
- Realign transducer to eliminate anisotropic effect

PATHOLOGY

General Features
- Etiology
  - Combination of intrinsic, extrinsic, biomechanical, and genetic factors
    - Intrinsic theory: Overuse, degeneration, and microtears
    - Extrinsic theory: Secondary to repeated impingement, steroid injections
    - Biomechanical: Eccentric tensile overload of rotator cuff tendons
- Genetics
  - Familial predisposition

Staging, Grading, & Classification
- Grade arbitrarily into mild, moderate, or severe depending on degree of thickening, hypoechogenicity, and loss of normal fibrillar pattern
  - Severity of tendinosis has implications for likelihood for tear and surgical outcome

Gross Pathologic & Surgical Features
- Thickened grayish or yellow-brown tendon rather than normal white color

Microscopic Features
- Collagen degeneration and disruption without inflammatory cell infiltrate
  - Normal architectural arrangement of collagen is impaired
  - ↓ in type I collagen content with ↑ in weaker type III collagen content
  - Tenocyte apoptosis (cell death) in some areas
  - Increase in tenocyte number in other areas with more rounded nuclei
  - Increase in extracellular proteoglycan ground substance with high concentration of glycosaminoglycan chains
- **Calcific tendinosis**
  - Deposition of hydroxyapatite crystals into matrix crystals vesicles
    - These vesicles coalesce to form foci of calcification
      - Chalk-like during formative and resting phases
      - Paste-like during resorptive phase

CLINICAL ISSUES

Presentation
- Most common signs/symptoms
  - Often subclinical; usually bilateral in older patients
  - Slowly progressive, poorly localized shoulder pain with decreased range of motion
  - Relationship between pain and severity of tendinosis is unclear
    - Tendinosis per se probably does not induce pain
      - Normal tendon does not contain neurons
      - High frequency of asymptomatic tendinosis
    - Pain most likely related to associated bursitis ± bone change or impingement
  - **Calcific tendinosis**
    - Resorptive phase is characterized by severe pain and limitation of movement
    - Shedding of crystals into bursa or into bone causes pain
- Clinical profile
  - Young athletes (usually precipitating factor, e.g., os acromiale or overhead sporting activity)
  - Older athletes or older nonathletic population (insidious onset, structural abnormality)

Demographics
- Age
  - Uncommon < 30 years, gradually increasing prevalence and severity with increasing years
- Gender
  - Slight female predominance

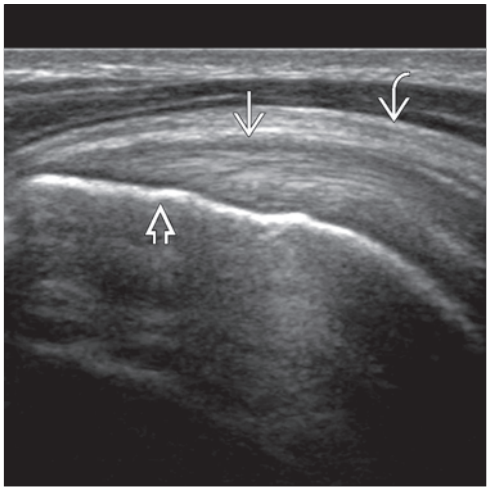
Treatment
- Physiotherapy
- Corticosteroids and long-acting local anesthetic injection to subacromial-subdeltoid bursa
  - Multiple steroid injections best avoided as may accelerate tendon degeneration
- Subacromial decompression
- **Calcific tendinosis**
  - Usually self limiting
  - Extracorporeal shock wave therapy (ESWT)
  - US- or fluoroscopic-guided lavage and aspiration
    - 1- or 2-needle technique
    - Warm saline (42˚C) lavage seems better at calcium dissolution than room temperature saline
      - Decreases procedure time and likelihood of post-procedural bursitis

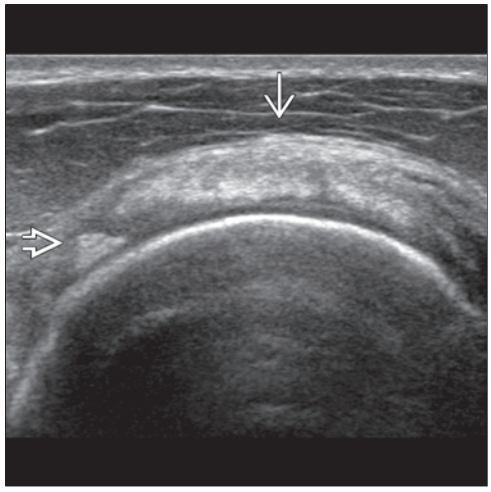
DIAGNOSTIC CHECKLIST

Consider
- Small tear if no abnormality on 1st inspection with ultrasound in patient with tendinosis and sudden deterioration in symptoms; check again
- Look especially at leading edge of tendon for small avulsive-type tear

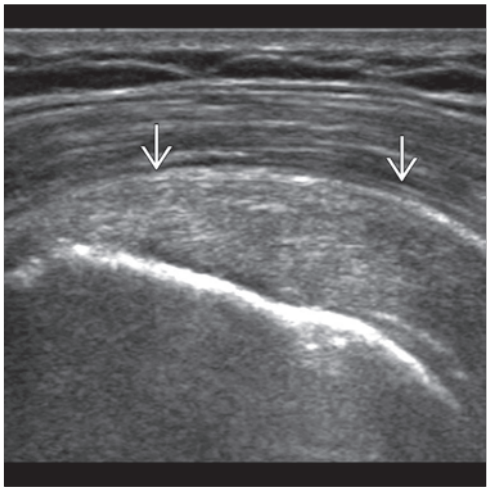
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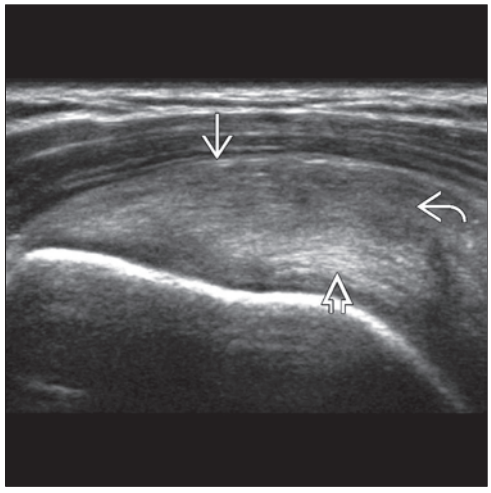
1. Yablon CM et al: Ultrasonography of the shoulder with arthroscopic correlation. Clin Sports Med. 32(3):391-408, 2013
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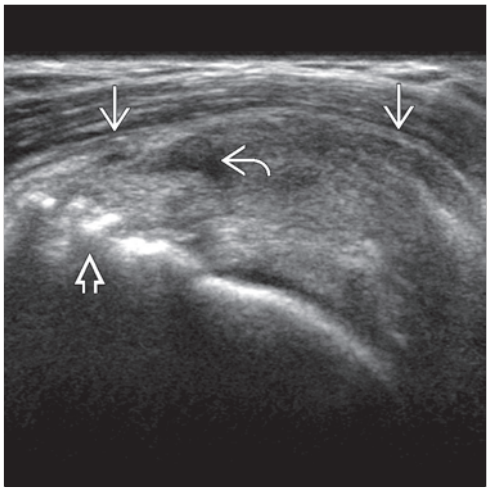


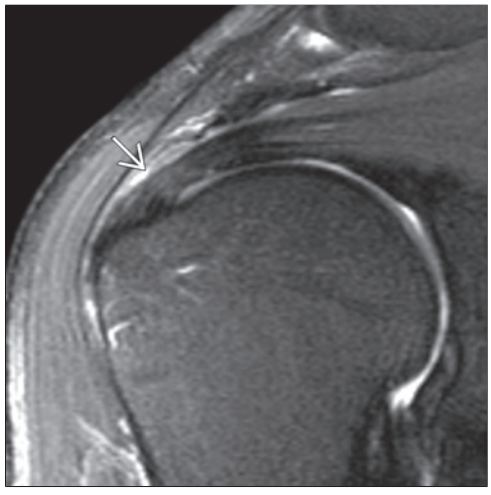
(Left) *Longitudinal ultrasound shows a normal, hyperechoic supraspinatus tendon of normal size and with a distinct fibrillary pattern. Note the smooth insertional area on the greater tuberosity of the humerus. The peribursal fat deep to the deltoid muscle is also shown.* ***(Right)*** *Transverse ultrasound of the same patient shows the normal, hyperechoic supraspinatus tendon in transverse section. Note the tendon of long head of biceps within the rotator interval.*





(Left) *Longitudinal ultrasound shows mild supraspinatus tendinosis. The tendon is mildly thickened and hypoechoic. Most of the hyperechoic fibers can still be identified.* ***(Right)*** *Transverse ultrasound shows moderate supraspinatus tendinosis. The tendon is more thickened and heterogeneous in appearance. There are ill-defined areas of hypoechogenicity interspersed with areas of preserved fibrillar pattern.*

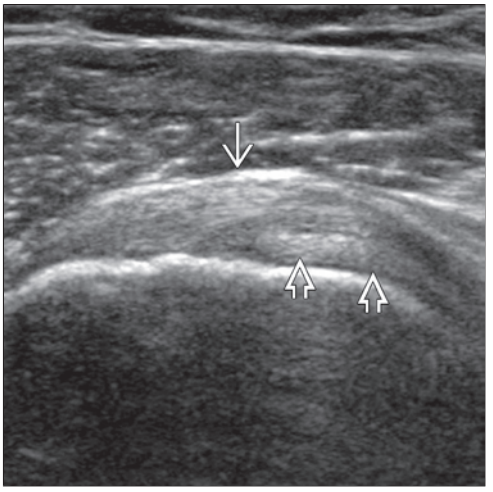


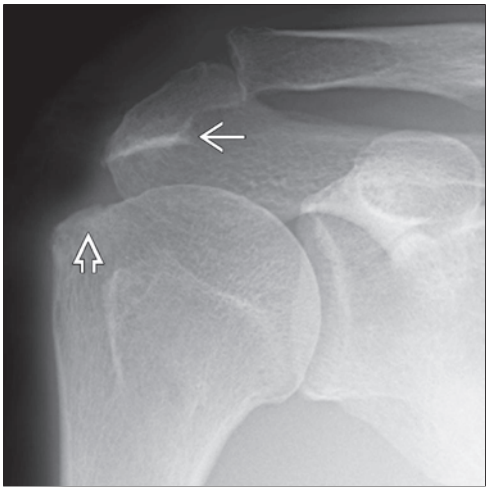


(Left) *Longitudinal ultrasound shows a markedly thickened and diffusely hypoechoic supraspinatus tendon. Normal linear fibrillar pattern is largely lost. The appearances are that of severe tendinosis. There is also severe cortical irregularity at the insertional area and some small intrasubstance tears.* ***(Right)*** *Oblique coronal T2 SPIR shows mild supraspinatus tendinosis with mild tendon hyperintensity. The fibrillar pattern of the tendon is better visualized by ultrasound than MR.*

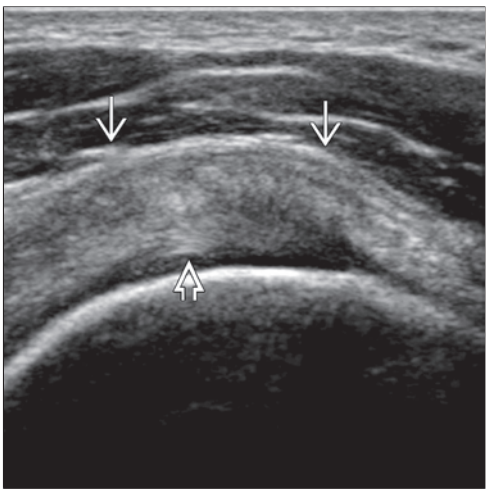
ROTATOR CUFF/BICEPS TENDINOSIS

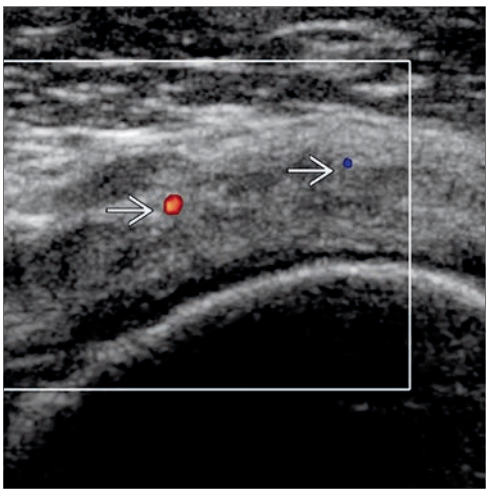
(Left) *Longitudinal ultrasound shows a normal supraspinatus tendon ➔. The hyperechoic fibers ➔ proximal to the insertional area are a prominent rotator cable in short axis. The rotator cable fibers run almost perpendicular to the other fibers.* ***(Right)*** *Frontal radiograph of the shoulder shows an acromial osteophytic spur ➔ with narrowing of the subacromial space, which predisposes the tendon to impingement and tendinosis. Note the mild cortical irregularity of the greater tuberosity ➔.*



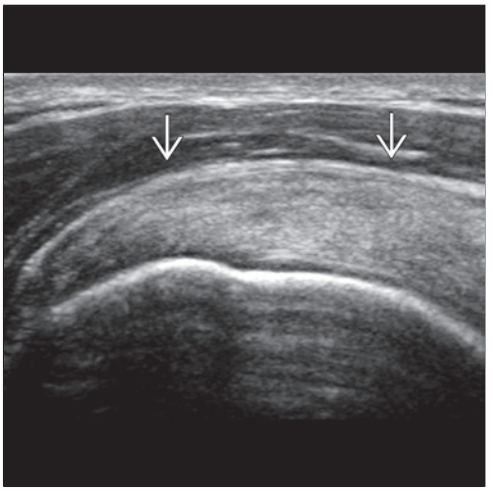


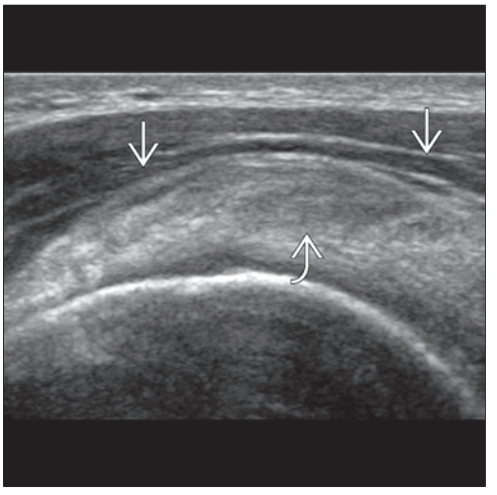
(Left) *Transverse ultrasound of the same patient as the previous image shows moderate supraspinatus tendinosis ➔ with an indistinct fibrillar pattern. Note the rotator cable ➔ in long axis. Rotator cable fibers are more noticeable with increasing age.* ***(Right)*** *Longitudinal color Doppler ultrasound of the same patient shows mild tendon hyperemia ➔. Unlike other tendons, hyperemia due to neovascularization is an uncommon feature of rotator cuff tendinosis and is not routinely assessed.*

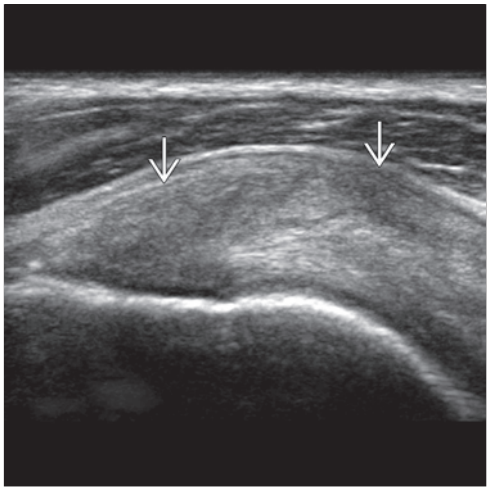


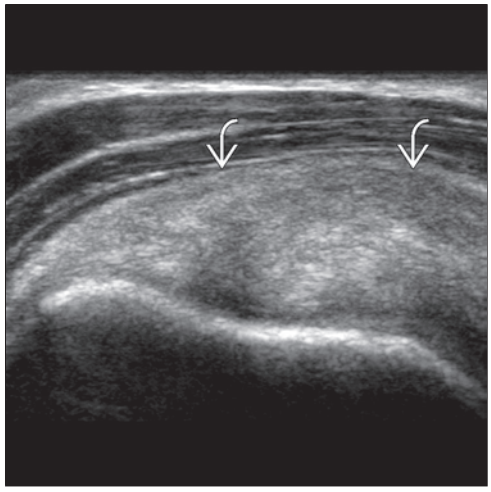


(Left) *Longitudinal ultrasound shows mild supraspinatus tendinosis. The tendon ➔ is mildly and diffusely thickened. Its normal hyperechogenicity and fibrillar pattern are largely preserved. It is important to grade tendinosis as mild, moderate, or severe.* ***(Right)*** *Transverse ultrasound of the same patient shows minimal distension of the subacromial subdeltoid bursa ➔ associated with supraspinatus tendinosis ➔.*

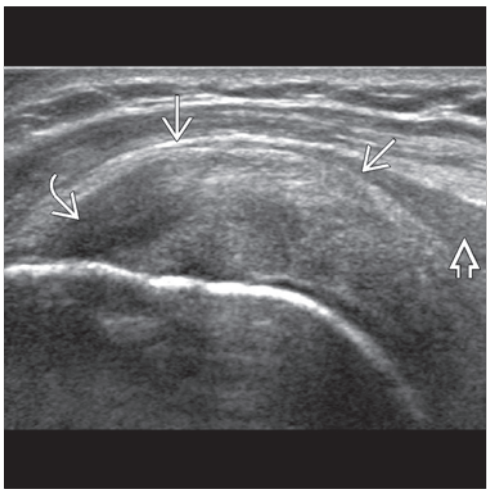


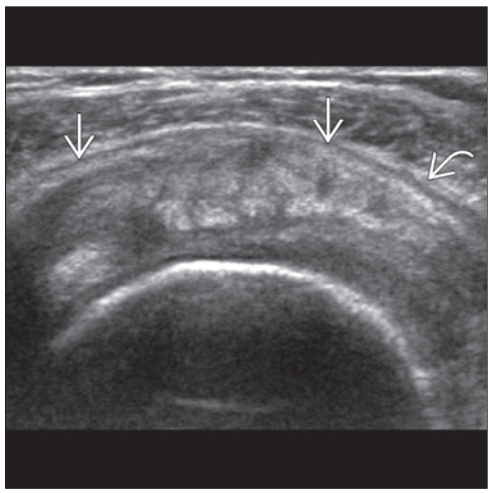




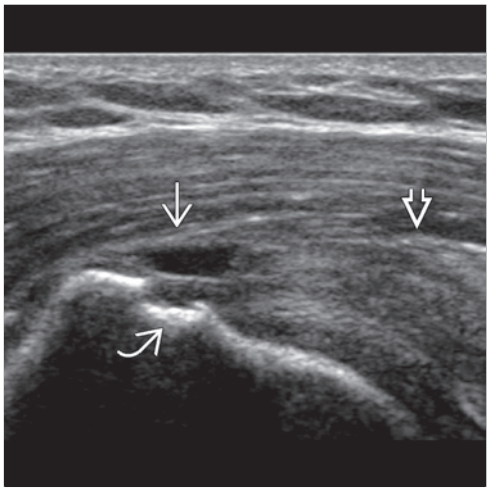


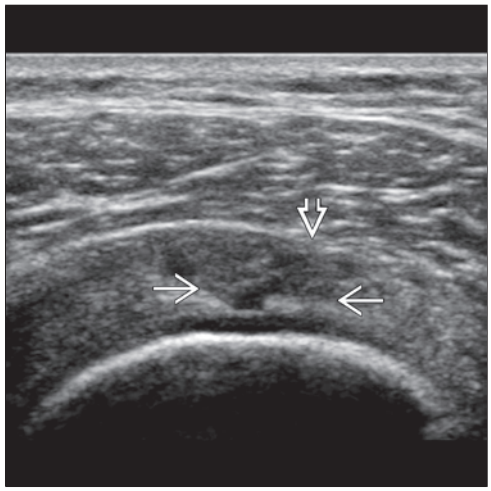
(Left) *Longitudinal ultrasound shows moderately severe supraspinatus tendinosis. The tendon is thickened, and the fibrillar structure is indistinct with ill-defined areas and lines of hypoechogenicity. One should use all 3 criteria to grade the severity of tendinosis.* ***(Right)*** *Transverse ultrasound of the same patient with moderate supraspinatus tendinosis shows mild bursal surface fibers fraying. This is a common feature in more severe degrees of tendinosis.*





(Left) *Longitudinal ultrasound shows moderate severity supraspinatus tendinosis. Note the hypoechoic anisotropic effect. There is distension of the subacromial-subdeltoid bursa with echogenic fluid, probably due to proteinaceous content.* ***(Right)*** *Transverse ultrasound of the same patient shows diffuse thickening and heterogeneous echogenicity of the supraspinatus tendon, associating with mild bursal surface fraying and mild subacromial-subdeltoid bursitis.*

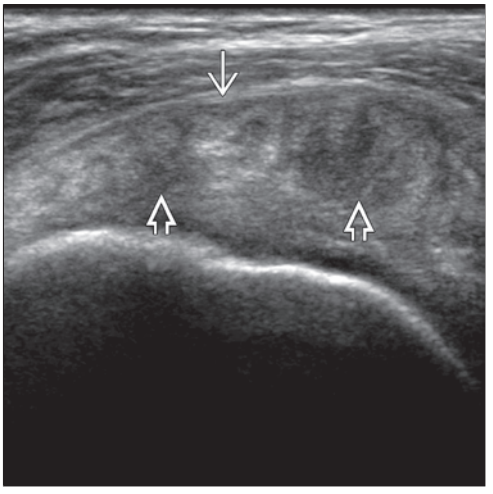


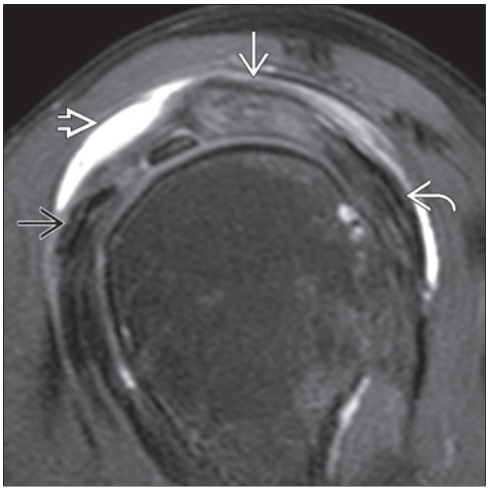


(Left) *Longitudinal ultrasound shows a partial thickness bursal-surface tear of the supraspinatus tendon at the insertional area. The tear is sharply demarcated against the background of moderate tendinosis. Note the cortical irregularity at the greater tuberosity.* ***(Right)*** *Transverse ultrasound of the same patient shows prominent contour flattening due to the partial tear within the supraspinatus tendon.*

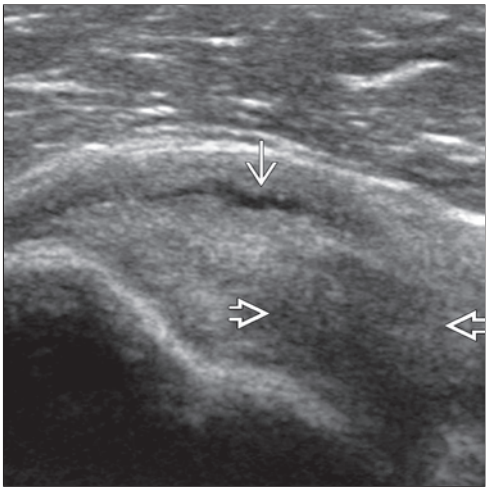
ROTATOR CUFF/BICEPS TENDINOSIS

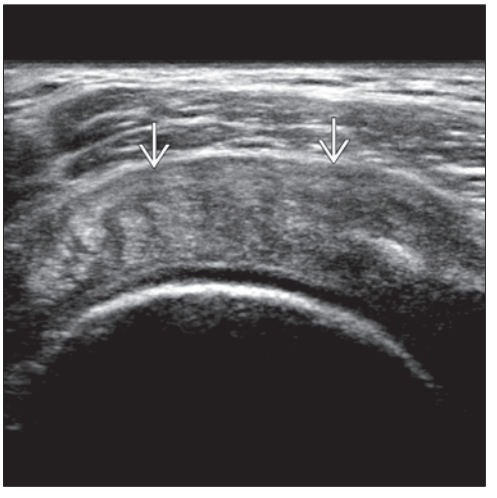
(Left) *Longitudinal ultrasound shows severe supraspinatus tendinosis with loss of normal fibrillar pattern and mildly indistinct areas of hypoechogenicity due to proteoglycan accumulation. There is no associated volume loss.* ***(Right)*** *Sagittal T2WI FS MR shows moderate supraspinatus tendinosis within moderate tendon thickening and hyperintensity. Moderate fluid distension in the subacromial-subdeltoid bursa is present. Note the normal subscapularis and infraspinatus tendons.*



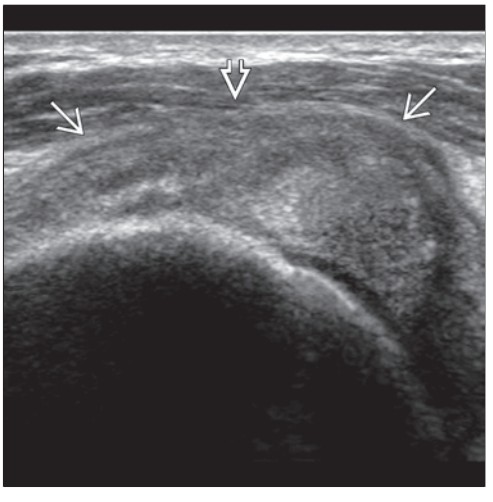


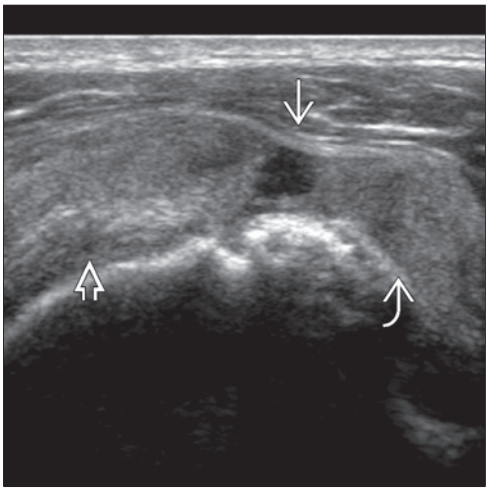
(Left) *Longitudinal ultrasound shows severe supraspinatus tendinosis with a well-demarcated, linear, hypoechoic intrasubstance tear. The other hypoechoic area within the tendon is a feature of tendinosis. There is a strong relationship between severity of tendinosis and tendon tear.* ***(Right)*** *Transverse ultrasound shows severe supraspinatus tendinosis. The supraspinatus tendon is severely and diffusely thickened with involvement of the anterior, mid, and posterior fibers.*

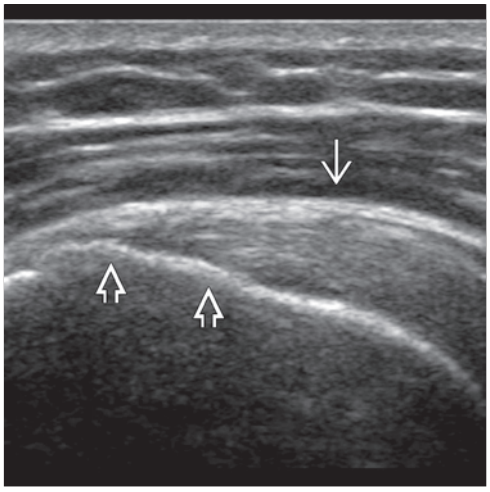


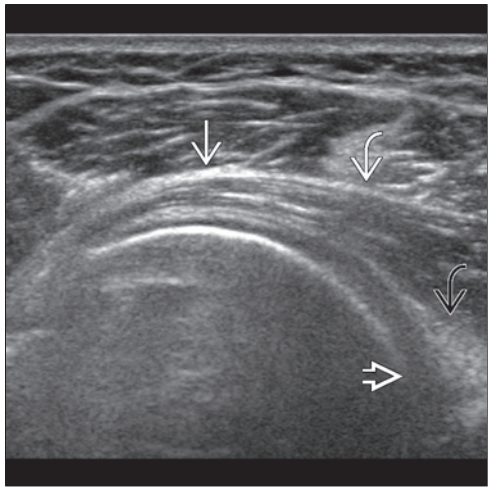


(Left) *Longitudinal ultrasound shows severe supraspinatus tendinosis. There is subtle bursal surface contour undulation present on this scan plane. Any contour deformity in tendinosis raises the suspicion of an underlying tendon tear.* ***(Right)*** *Transverse ultrasound of the same patient shows a full thickness partial tear of the midfibers of the supraspinatus. Note the severe thickening of the anterior and posterior fibers.*

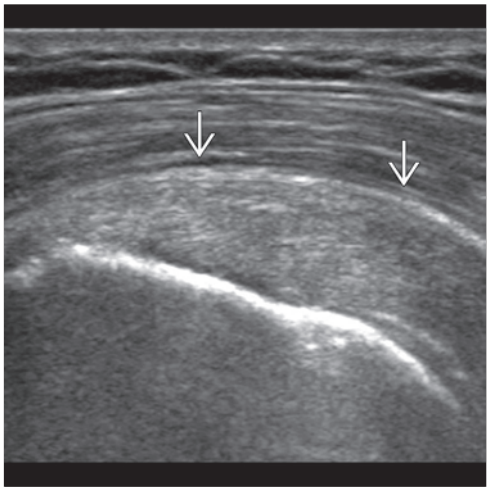


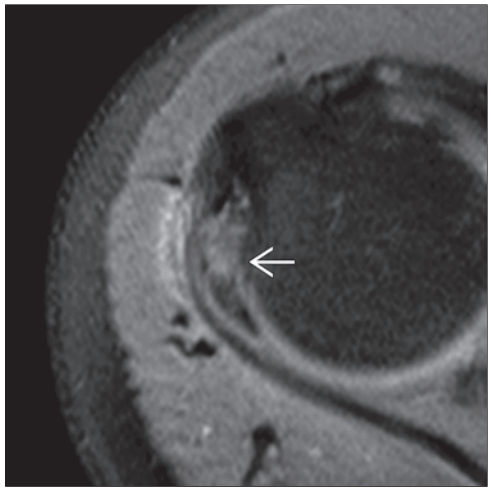




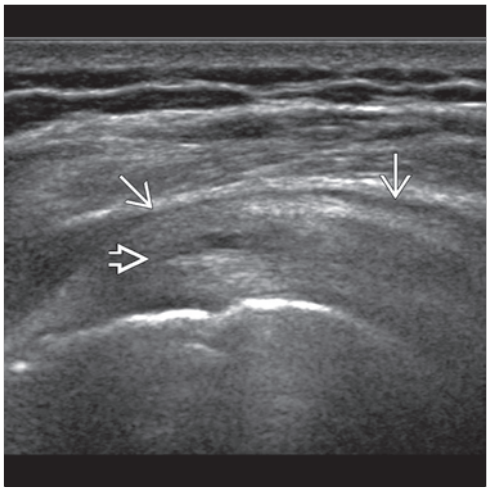


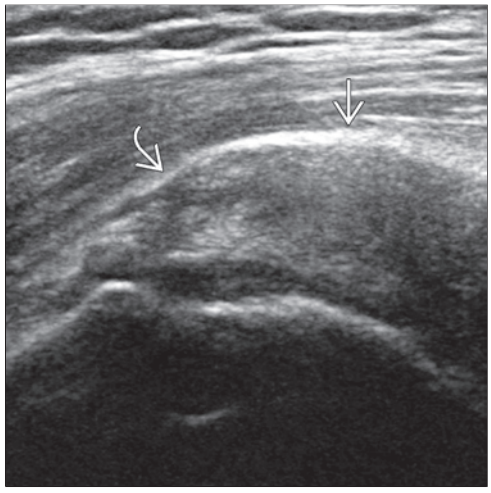
(Left) *Longitudinal ultrasound shows a normal infraspinatus tendon* ➔ *inserting into the middle facet of the greater tuberosity* ➔*. The infraspinatus, supraspinatus, and teres minor are inseparable at insertion.* ***(Right)*** *Longitudinal ultrasound shows the infraspinatus tendon* ➔ *at a slightly more proximal portion. In this position, the myotendinous junction* ➔ *as well as the posterior glenohumeral joint* ➔ *can be visualized. Note the posterior glenoid labrum* ➔*.*





(Left) *Longitudinal ultrasound shows mild thickening and hypoechogenicity of the infraspinatus tendon* ➔ *indicative of mild tendinosis.* ***(Right)*** *Axial PD FSE FS MR shows thickening and hyperintense signal of the insertional fibers of the infraspinatus tendon* ➔ *consistent with moderate tendinosis. You can appreciate how MR gives a global picture, though does not provide the same fine tendon detail as an ultrasound.*

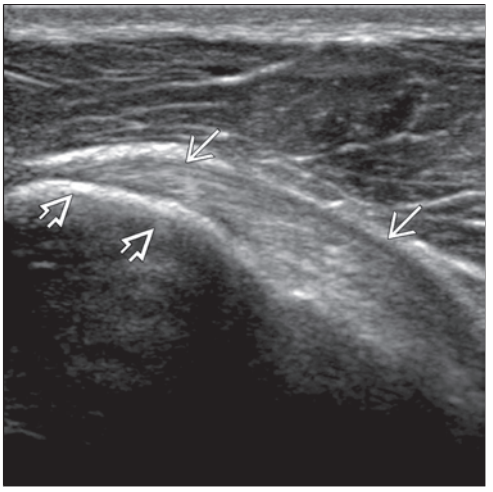


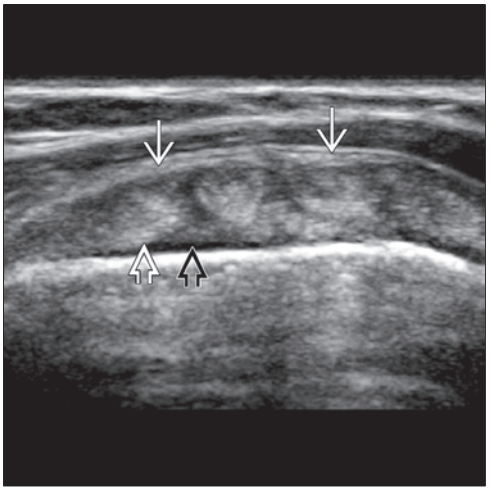


(Left) *Longitudinal ultrasound shows moderate severity infraspinatus tendinosis. The tendon* ➔ *is moderately thickened and hypoechoic. There is an intrasubstance tear* ➔ *without extension to either the bursal or articular surface present.* ***(Right)*** *Longitudinal ultrasound show a diffusely thickened and hypoechoic infraspinatus tendon* ➔ *indicative of severe infraspinatus tendinosis. There is a small, irregular bursal surface tear* ➔ *near the insertion.*

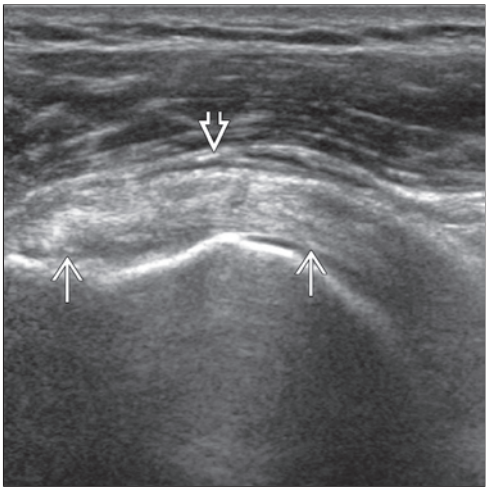
ROTATOR CUFF/BICEPS TENDINOSIS

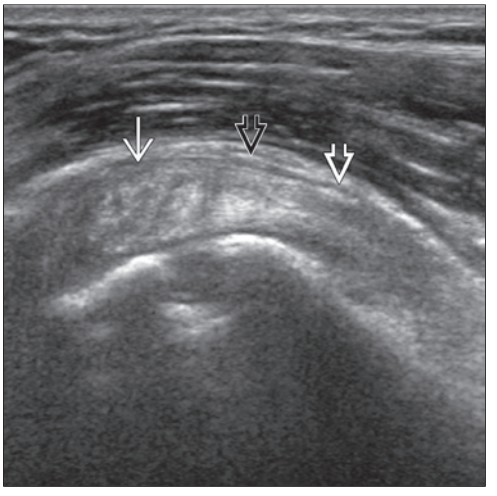
(Left) *Longitudinal ultrasound shows a normal subscapularis tendon ➔ inserting onto the lesser tuberosity ➔ of the humerus. The tendon is normal in size with distinct hyperechoic fibers.* ***(Right)*** *Transverse ultrasound shows normal appearances of the subscapularis tendon ➔ in the transverse section. The distinctive bundle heterogeneity is due to the juxtaposition of hyperechoic tendon bundles ➔ with hypoechoic muscle ➔.*



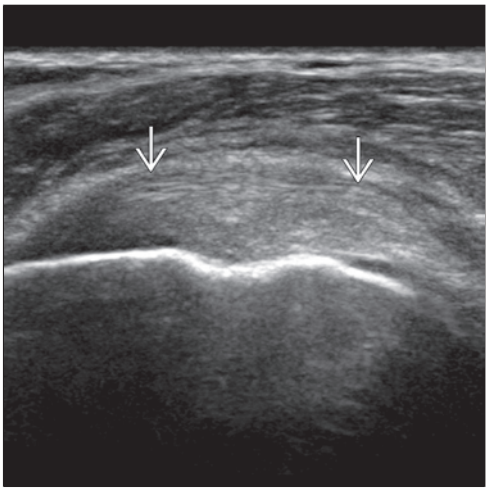


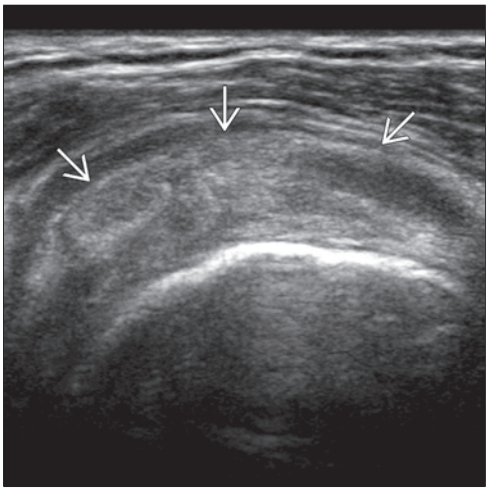
(Left) *Longitudinal ultrasound shows mild to moderate subscapularis tendinosis ➔ associated with mild fluid distension within the subcoracoid recess ➔.* ***(Right)*** *Transverse ultrasound of the same patient shows the superior subscapularis fibers ➔ are thickened to a greater degree than the mid ➔ and inferior ➔ fibers. Tendinosis preferentially affects the superior subscapularis fibers.*

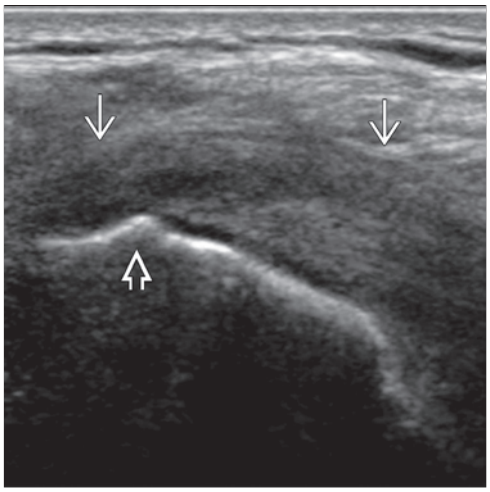


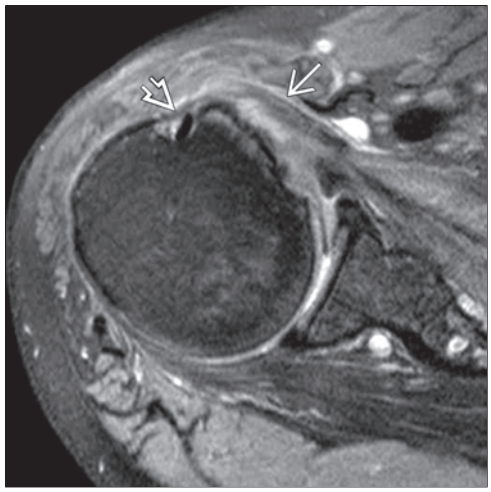


(Left) *Longitudinal ultrasound shows moderate to severe subscapularis tendinosis ➔.* ***(Right)*** *Transverse ultrasound of the same patient shows diffuse thickening of superior, mid, and inferior fibers of the subscapularis tendon ➔. Distinction between the tendon fibers and muscle fibers is diminished as the severity of tendinosis increases. The appearances are those of moderate to severe tendinosis.*

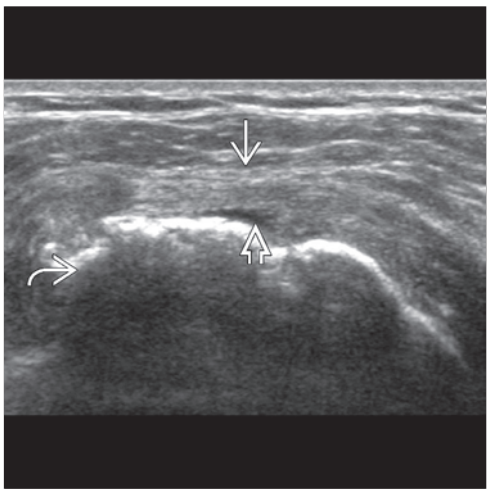


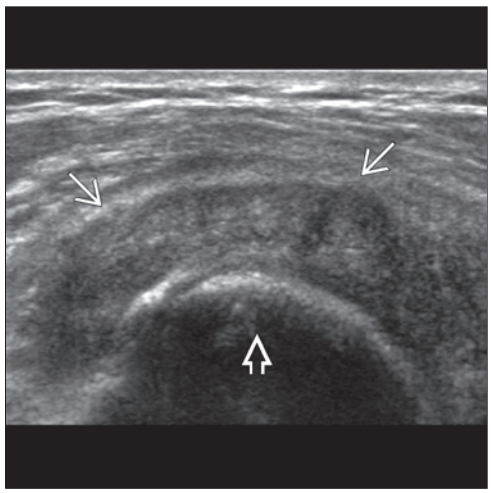




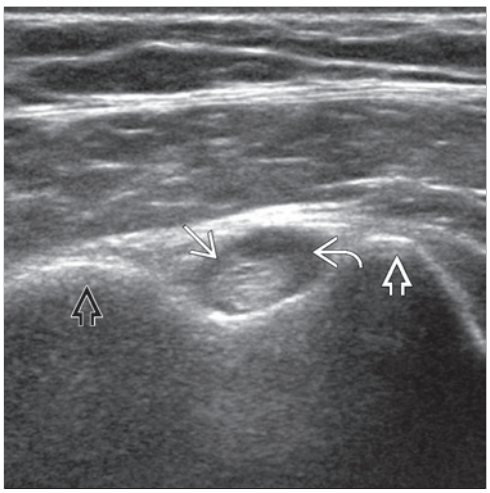


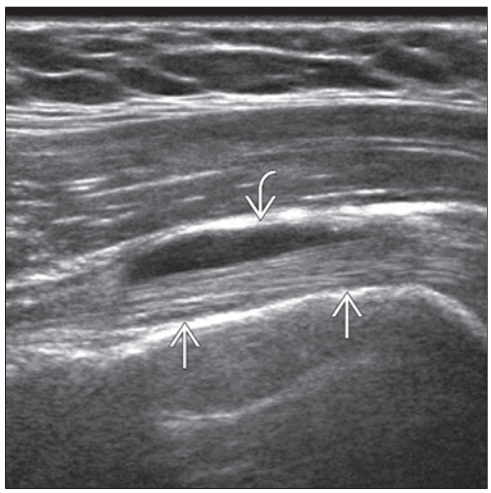
(Left) *Longitudinal ultrasound shows severe subscapularis tendinosis with a severely thickened and diffusely hypoechoic subscapularis tendon ➔ associated with mild cortical irregularity of the lesser tuberosity ➔.* ***(Right)*** *Axial PD FSE FS MR of the same patient shows severe subscapularis tendinosis ➔ with hyperintense signal within the thickened tendon. Note the normal long head biceps tendon within the bicipital groove ➔.*





(Left) *Longitudinal ultrasound shows severe cortical irregularity of the lesser tuberosity ➔. There is subscapularis tendinosis associated with articular surface avulsive-type tear ➔ near the insertion. Note flattening of the tendon surface contour ➔ due to the tendon tear.* ***(Right)*** *Transverse ultrasound of the same subscapularis tendon ➔ proximal to the tear shows severe background tendinosis with diffuse thickening and hypoechogenicity. Note the lesser tuberosity ➔.*

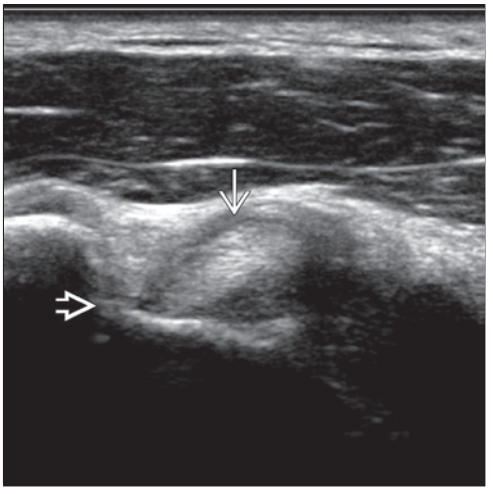


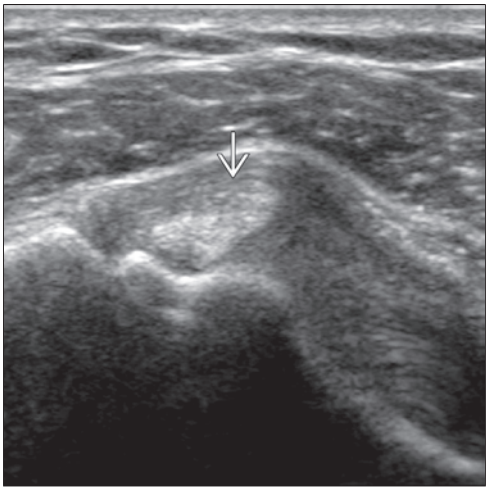


(Left) *Transverse ultrasound shows a normal biceps tendon ➔ within the bicipital groove. There is a small amount of fluid ➔ within the biceps tendon sheath. Note the medial ➔ and lateral ➔ lips of the bicipital groove.* ***(Right)*** *Longitudinal ultrasound of the same patient shows the normal long head of biceps tendon ➔. As the biceps tendon sheath ➔ communicates with the glenohumeral joint, fluid in 1 compartment mirrors that in the other compartment.*

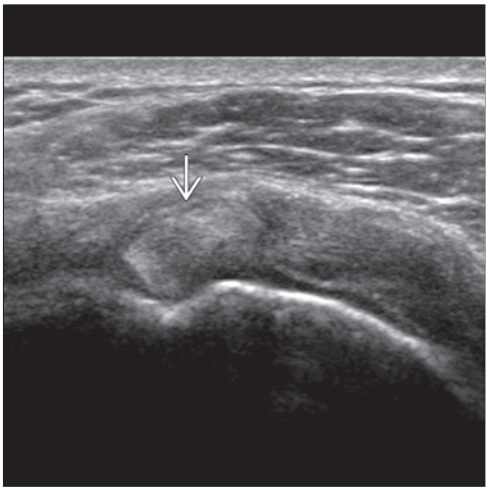
ROTATOR CUFF/BICEPS TENDINOSIS

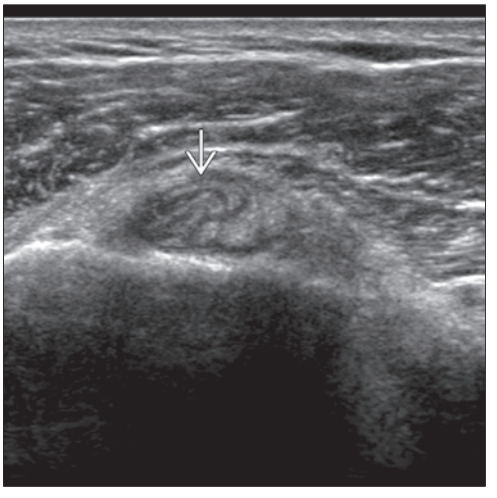
(Left) *Transverse ultrasound shows the normal oblong configuration of the long head of the biceps tendon* ➔ *at the uppermost portion of the bicipital groove* ⇨. ***(Right)*** *Transverse ultrasound shows mild tendinosis of the long head of the biceps tendon* ➔ *with mild tendon swelling leading to a slightly ovoid, cross-sectional contour. Tendinosis of the biceps long head most commonly affects the tendon at the uppermost portion of the bicipital groove.*



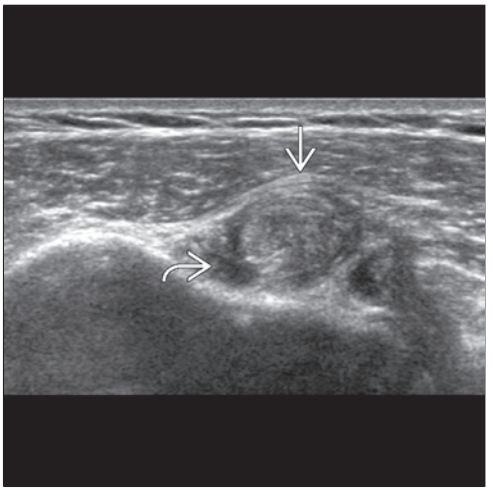


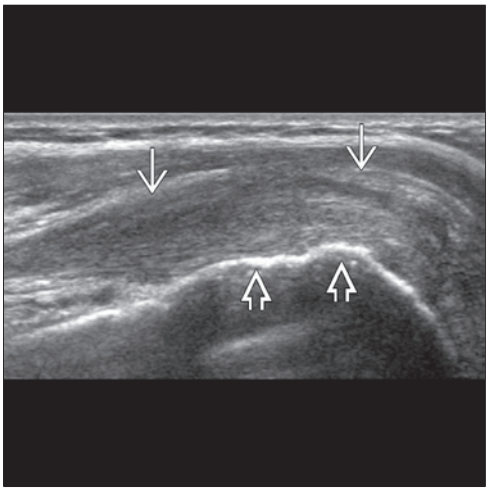
(Left) *Transverse ultrasound scan shows moderate biceps tendinosis* ➔. *The tendon is more hypoechoic and more thickened than normal. The appearances are those of moderate biceps tendinosis.* ***(Right)*** *Transverse ultrasound shows severe biceps tendinosis* ➔ *at the upper end of the bicipital groove. The tendon is moderately swollen and heterogeneous in echotexture with several longitudinal splits. Longitudinal splits tears extending for about 1 cm are common in severe biceps tendinosis.*

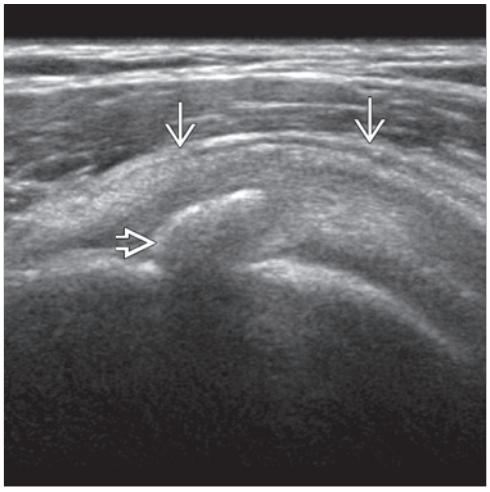


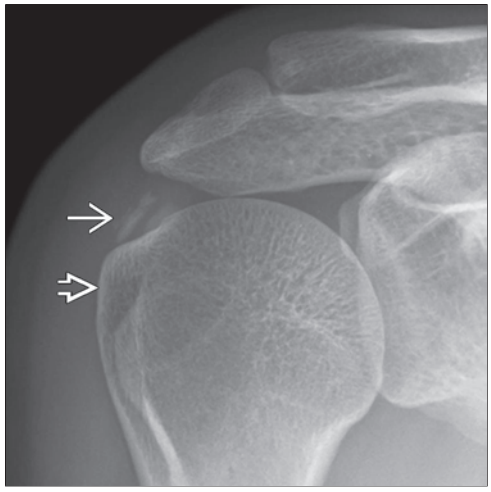


(Left) *Transverse ultrasound shows severe biceps tendinosis* ➔. *The tendon is rounded and heterogeneous with loss of fibrillar pattern. Note the minimal degree of synovial sheath thickening and fluid* ➔. ***(Right)*** *Longitudinal ultrasound of the same patient shows severe thickening of the biceps tendon* ➔, *particularly at the proximal end of the bicipital groove. There is mild cortical irregularity* ⇨ *of the bicipital groove.*

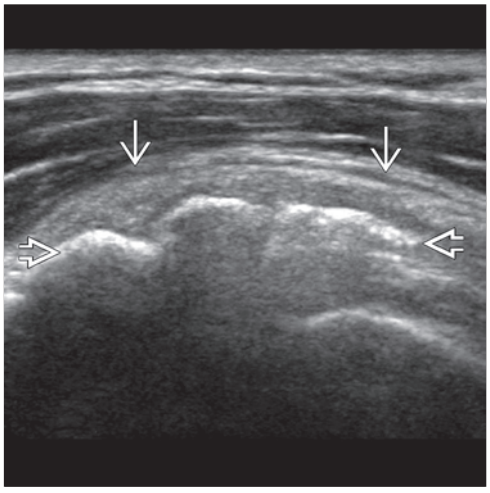






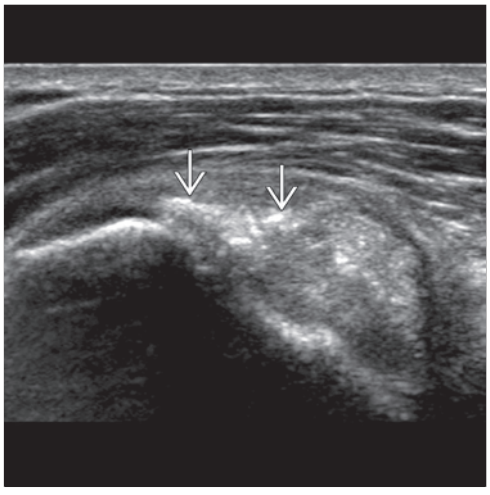


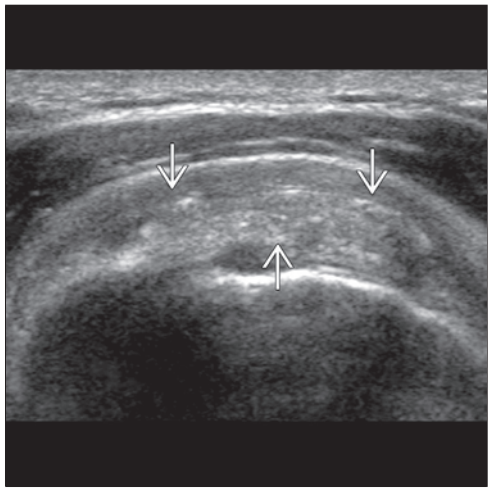
(Left) *Longitudinal ultrasound shows a medium-sized area of calcific deposition* ➔ *with posterior acoustic shadowing at the supraspinatus insertional area. There is mild background tendinosis* ➔*. This can be summarized as mild supraspinatus tendinosis with a medium-sized area of calcific deposition.* ***(Right)*** *Frontal radiograph of the same patient shows the calcific focus* ➔ *close to the greater tuberosity* ➔*. Ultrasound is more sensitive than radiography at depicting calcific deposition within tendons.*





(Left) *Longitudinal ultrasound shows mild supraspinatus tendinosis* ➔ *with large clump-like areas of calcification deposition* ➔ *within the tendon substance. This can be summarized as mild supraspinatus tendinosis with severe calcific deposition.* ***(Right)*** *Longitudinal ultrasound shows a small, poorly defined area of faint calcification* ➔ *within the supraspinatus tendon. Only mild background tendinosis is present.*





(Left) *Transverse ultrasound of the supraspinatus tendon shows several quite discrete areas of calcific deposition* ➔ *close to the tendon insertion. Moderate background tendinosis is present.* ***(Right)*** *Transverse ultrasound shows calcific supraspinatus tendinosis. There are small faint echogenic foci of calcification* ➔ *scattered throughout the supraspinatus tendon.*

ROTATOR CUFF/BICEPS TENDON TEAR

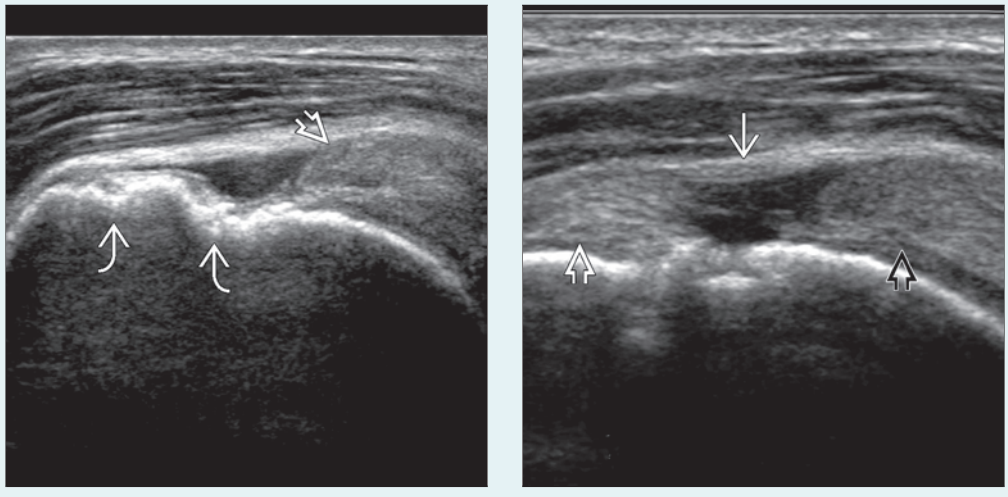
Key Facts

Terminology
- Partial thickness, full thickness, or complete rotator cuff ± biceps tendon tear

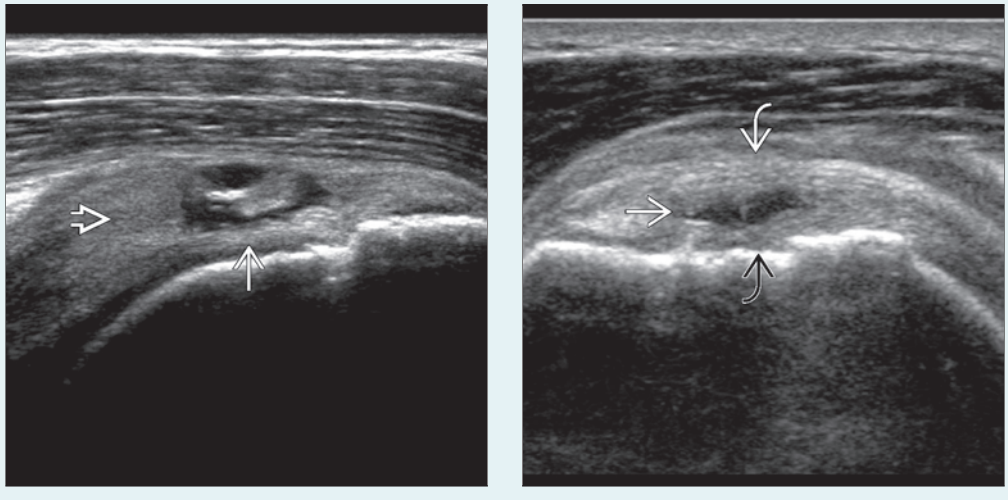
Imaging
- US and MR have comparable accuracy for rotator cuff and biceps tendon tear detection
- Supraspinatus tendon tears most common close to or at insertional area, especially anterior fibers
  - Most tears are avulsive type with retraction from insertional area
  - Pay particular attention to leading edge of supraspinatus tendon
- Isolated tear of infraspinatus tendon is less common
- Tears in normal tendons are less common

Diagnostic Checklist
- Discontinuity of tendon filled with anechoic fluid
  - Focal flattening or concavity of bursal surface
- Complete tear with retraction: Nonvisualization of tendon
  - ± "cartilage interface" sign, ± superior migration humeral head
- For partial tears, measure anteroposterior and mediolateral dimensions of tear
  - Determine whether tear located in anterior, middle, or posterior fibers of tendon
- For partial thickness tears, note % depth of tear relative to tendon thickness
  - Assess whether bursal sided, articular sided, or intrasubstance
- Grade severity of tendinosis (as mild, moderate, or severe)
- Recognition of intrasubstance tear more difficult in moderate to severe tendinosis
  - Intrasubstance tear: Linear, irregular, sharp, hypoechoic area ± volume loss

(Left) *Longitudinal ultrasound shows full thickness tear of supraspinatus tendon midfibers. Gap is filled with anechoic fluid with fibers retracted medially. Note cortical irregularity of the insertional area.* ***(Right)*** *Transverse ultrasound of the same patient shows full thickness tear of supraspinatus tendon midfibers. Anterior fibers and posterior fibers remain intact. Note the loss of volume with bursal surface contour depression.*



(Left) *Longitudinal ultrasound shows a near full thickness partial tear of the supraspinatus tendon. The gap is filled with anechoic fluid. There are a few intact fibers close to the articular surface with moderate severity supraspinatus tendinosis.* ***(Right)*** *Longitudinal ultrasound shows an irregular intrasubstance tear within supraspinatus tendon midfibers. The tear does not extend to the bursal or articular surface.*



ROTATOR CUFF/BICEPS TENDON TEAR

TERMINOLOGY

Definitions

- Complete tear: All fibers of tendon are torn
- Partial tear: Some fibers of tendon are torn
  - Full thickness tear: Tear involves only part of tendon (e.g., anterior, mid-, or posterior supraspinatus fibers)
  - Partial thickness tear: Tear involves only part of tendon depth (e.g., bursal surface, intrasubstance, articular surface tear)
    - Intrasubstance tear does not extend to bursal or articular surface (not seen at arthroscopy)
- Massive tear: Complete tear of supraspinatus and infraspinatus tendons

IMAGING

General Features

- Best diagnostic clue
  - Discontinuity of tendon or tendon torn from its insertional area
- Location
  - Most rotator cuff tendon tears involve supraspinatus
    - Anterior fibers most commonly torn, particularly at leading edge
    - Tear may extend posteriorly to infraspinatus or anteriorly to biceps pulley and subscapularis
      - Biceps pulley tear → biceps tendon subluxation
    - Most supraspinatus and infraspinatus tears are avulsive in type (i.e., tendon stripped from Sharpey fibers at insertional area)
  - Isolated tear of infraspinatus tendon uncommon
    - Supra- and infraspinatus closely applied at insertion; not easy to distinguish posterior supraspinatus fibers from anterior infraspinatus fibers
    - Supraspinatus insertion is 20-25 mm wide
      - Tear extending posteriorly > 25 mm from biceps likely to involve infraspinatus tendon

Radiographic Findings

- Radiography
  - Cortical irregularity, subcortical sclerosis, and cysts of greater tuberosity
    - Feature of chronic tendinosis
  - Superior migration humeral head with ↓ subacromial space in massive rotator cuff tears
    - Acromiohumeral distance < 7 mm
  - Acromial osteophytic spur, hooked (type III) acromion, acromioclavicular osteoarthrosis (on supraspinatus outlet view, modified Y view)

MR Findings

- T1WI
  - ↑ tendon signal intensity due to tendinosis
  - Structural abnormalities predisposing to tear
    - Acromial osteophytic spurs or hook, thickened coracoacromial ligament, acromioclavicular osteoarthrosis
    - Better seen on MR than US
  - Rotator cuff muscle atrophy
    - Predictor of negative outcome after surgery
- T2WI
  - Fluid-filling complete or incomplete gap in tendon
    - ± Fluid within subacromial bursa (more consistently seen on MR than US)
  - MR arthrography is possibly more sensitive for articular surface tear

Ultrasonographic Findings

- Discontinuity or gap within tendon filled with clear hypoechoic fluid (primary sign)
  - Gap filled with blood may appear as isoechoic or hypoechoic
  - Most tears are avulsive type with retraction from insertional area
  - ± focal flattening or concavity of convex bursal tendon surface, undulation of smooth tendon contour
  - ± gas locules with "comet tail" artifacts in acute tear
- Intrasubstance tear: Linear irregular sharp hypoechoic area within tendon substance
- Complete tear with retraction: Nonvisualization of tendon
  - "Cartilage interface" sign with clear visualization of humeral head cartilage
  - Superior migration of humeral head
- Features of tendinosis; tears in normal tendons are uncommon
- Fluid within subacromial-subdeltoid bursa
- Cortical irregularity of tendon insertional area
- Muscle atrophy
- Biceps tendon tears: Either split tears or complete transverse tears
  - Most tears preferentially affect tendon at uppermost part of bicipital groove
  - Both tears are more common in preexisting biceps tendinosis
    - Tendinosis particularly affects uppermost part of biceps tendon in bicipital groove
      - ± bony irregularity of bicipital groove margins
  - Complete tears seen as empty bicipital groove
    - Collapsed synovial sheath ± synovial hypertrophy may simulate attenuated biceps tendon
    - Retracted biceps muscle belly in arm may simulate soft tissue mass

Imaging Recommendations

- Best imaging tool
  - US
    - Comparable accuracy to MR for detecting rotator cuff or biceps tendon tears
      - Patients prefer US to MR
- Protocol advice
  - High-frequency transducer; systematic examination
    - Pay particular attention to anterior leading edge of supraspinatus tendon, particularly if unexplained bursal fluid
    - Make sure all insertional area is covered with tendon
  - For partial tears, measure anteroposterior and mediolateral dimension of tear
    - Determine whether tear is located in anterior, middle, or posterior fibers
  - For partial thickness tears, note % depth of tear relative to tendon thickness
    - Assess whether bursal sided, articular sided, or intrasubstance

- Be wary of diagnosing supraspinatus or infraspinatus musculotendinous junction tears with US
  - These tears are uncommon, and accuracy of US ↓ in this area
- Grade tendinosis severity (mild, moderate, or severe)
  - Difficult in acute tears as tendon is often swollen
- Recognition of intrasubstance tear is more difficult in moderate to severe tendinosis
  - Intrasubstance tear: Linear, irregular, sharp, hypoechoic area ± volume loss
- Muscle atrophy is assessed on longitudinal scanning over posterior aspect of scapula
  - ↓ volume, ↑ echogenicity (should be = trapezius)
- Always examine uppermost portion of biceps tendon in bicipital groove
  - Also grade biceps tendinosis as mild, moderate, or severe
  - Assess for synovial proliferation around uppermost part of biceps tendon
  - If empty bicipital groove, check for medial subluxation of biceps tendon
  - Examine mid to upper arm to confirm retracted long head of biceps muscle belly
    - Muscle belly not retracted if tendon is subluxed rather than torn

DIFFERENTIAL DIAGNOSIS

Bursitis
- Fluid distension of entire subacromial-subdeltoid bursa
- Fluid first accumulates under and adjacent to acromion, lateral aspect of upper arm, and medial to coracoid process

Rotator Cuff and Biceps Tendinosis
- Thickened tendon with loss of fibrillar pattern and increasing hypoechogenicity
  - Prevalence increases with age
- Biceps tendinosis often accompanies rotator cuff tendinosis

Calcific Tendinitis
- Calcium hydroxyapatite deposition
  - Echogenic foci within tendon substance ± acoustic shadowing

PATHOLOGY

General Features
- Etiology
  - Rare in patients < 40 years old
  - Partial or full thickness rotator cuff tear in 60% of symptomatic patients > 60 years old
    - Usually on background of tendinosis
      - Spontaneous tears occur with severe tendinosis
  - Tears in normal tendons are usually due to macrotrauma
- Associated abnormalities
  - Superior labrum anterior to posterior (SLAP) tears are associated with articular surface partial tears
  - Posterosuperior humeral head impaction with internal impingement

Gross Pathologic & Surgical Features
- Thickened, indurated tendon edges
- Hemorrhage in interstitial tears
- Associated subacromial-subdeltoid bursitis

Microscopic Features
- Collagen degeneration without inflammatory cells
- Increased levels of smooth muscle actin (SMA)
  - SMA-positive cells + glycosaminoglycan and proteoglycan promote retraction of torn fibers

CLINICAL ISSUES

Presentation
- Most common signs/symptoms
  - Insidious onset of pain in adult patient with impingement syndrome
  - Persistence of pain following acute trauma
  - Weakness of abduction
  - Impingement signs
  - Night pain
  - Pain during descent of abducted arm (arc of pain)
  - Weakness of external rotation: Infraspinatus tear
  - Partial tears are more painful than full thickness tears
- Clinical profile
  - Athlete; patient > 40 years old with impingement

Natural History & Prognosis
- Many partial thickness tears progress to full thickness tears within 2 years
- Many asymptomatic tears can become symptomatic
- Smaller tears may heal with cessation of impingement activity and physiotherapy

Treatment
- Autologous blood injection under US guidance for partial tears
  - Physiotherapy for minor partial tears
- Arthroscopic debridement, suture anchoring, and subacromial decompression for larger tears
  - Muscle atrophy can improve with successful repair

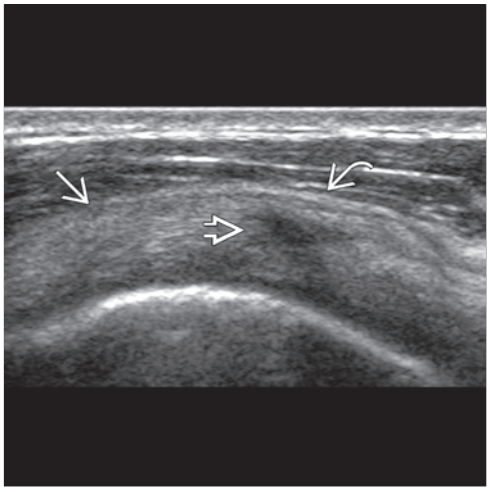
DIAGNOSTIC CHECKLIST

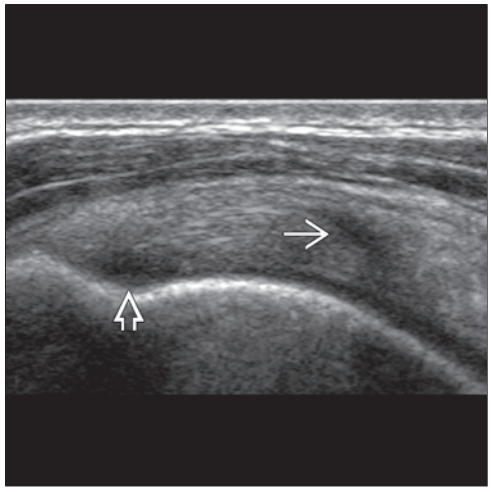
Consider
- Small supraspinatus surface tear or leading edge tear if unexplained bursal fluid is seen
  - Pay particular attention to tendon contour and anterior edge of supraspinatus at insertional area

Image Interpretation Pearls
- Systematic examination for secondary signs as well as primary sign of tear
  - Cortical irregularity insertional area
  - Bursal fluid
  - Flattening or concavity of tendon contour ("flagging peri-bursal fat" sign)

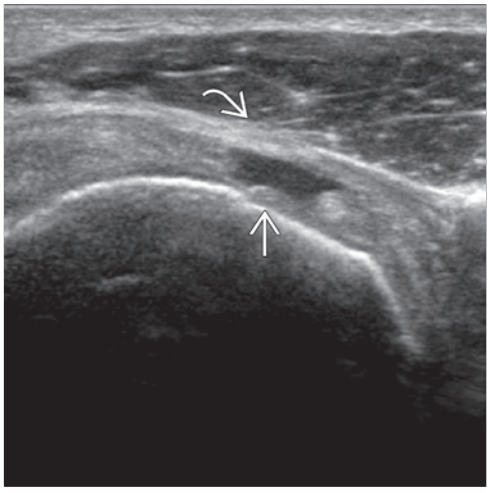
SELECTED REFERENCES

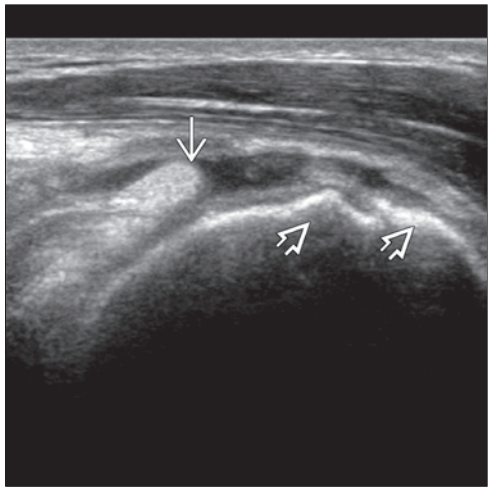
1. Nazarian LN et al: Imaging algorithms for evaluating suspected rotator cuff disease: Society of Radiologists in Ultrasound consensus conference statement. Radiology. 267(2):589-95, 2013
2. Jacobson JA: Shoulder US: anatomy, technique, and scanning pitfalls. Radiology. 260(1):6-16, 2011



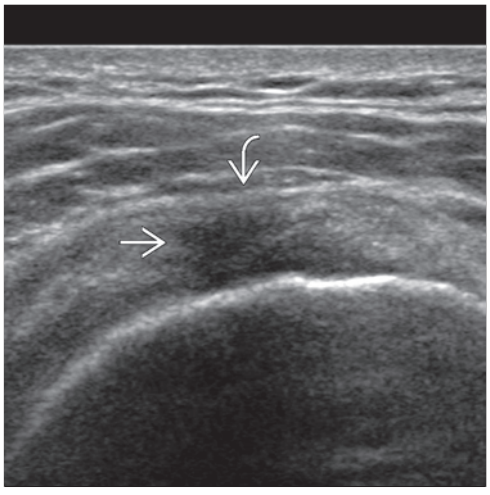


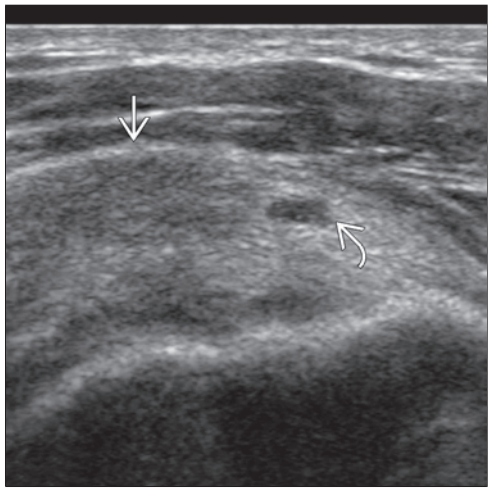
(Left) *Transverse ultrasound shows mild supraspinatus tendinosis ➔ with a well-defined irregular hypoechoic area ➔ in the anterior fibers due to an intrasubstance tear. Note the mild associated bursal surface contour flattening ➔.* ***(Right)*** *Longitudinal ultrasound of the same patient shows an intrasubstance tear ➔ just proximal to the insertional area. All rotator cuff tendon tears should be confirmed in 2 planes. The hypoechoic area ➔ near the greater tuberosity is due to anisotropy.*





(Left) *Transverse ultrasound shows full thickness tear ➔ of supraspinatus tendon midfibers. The gap is filled with anechoic fluid. The overlying peribursal fat ➔ is made more prominent.* ***(Right)*** *Longitudinal ultrasound of the same patient shows how the torn fibers ➔ are retracted medially from the insertional area in the greater tuberosity. The insertional area at the greater tuberosity is bare and irregular ➔. The retraction gap is filled with fluid.*

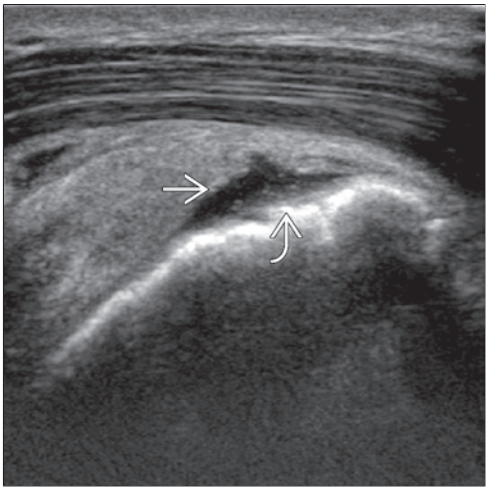


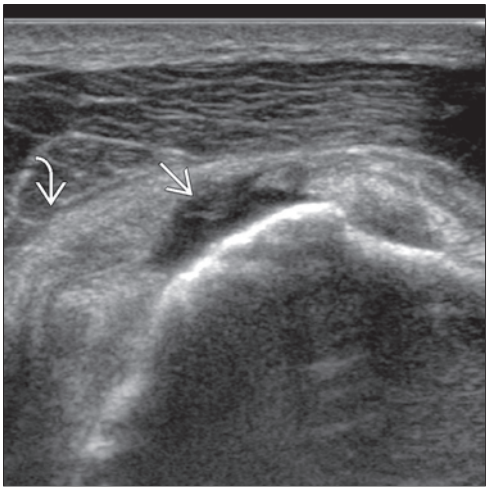


(Left) *Transverse ultrasound shows a full thickness tear ➔ of the supraspinatus tendon with a mild focal bursal surface contour depression ➔.* ***(Right)*** *Longitudinal ultrasound shows a diffusely thickened and mildly hypoechoic supraspinatus tendon due to severe tendinosis ➔ of these anterior fibers. There is a more discrete small partial thickness intrasubstance tear present ➔. The fibrillar echotexture of the supraspinatus tendon is less distinct than usual.*

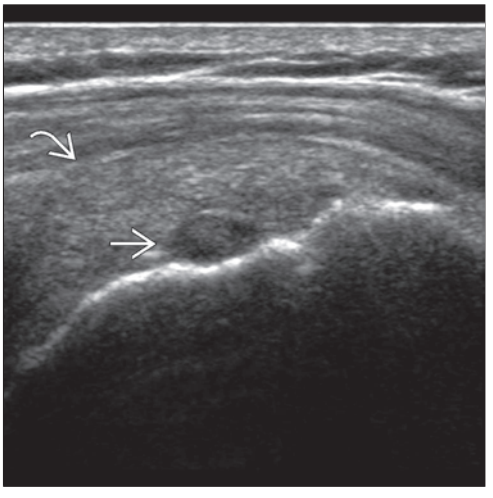
ROTATOR CUFF/BICEPS TENDON TEAR

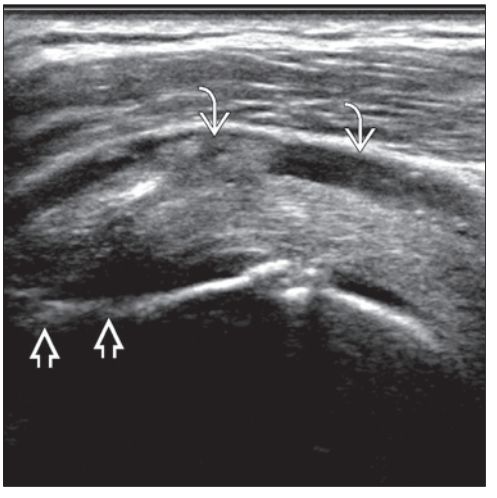
(Left) *Longitudinal ultrasound shows a full thickness avulsive-type tear of the supraspinatus tendon. The fibers have stripped or retracted from the insertional area.* ***(Right)*** *Transverse ultrasound shows the same tear at the anterior fibers of the supraspinatus tendon. The gap is filled with hypoechoic fluid. Moderate tendinosis of the remaining supraspinatus tendon is present. The anteroposterior and mediolateral dimensions of the tear should be measured.*



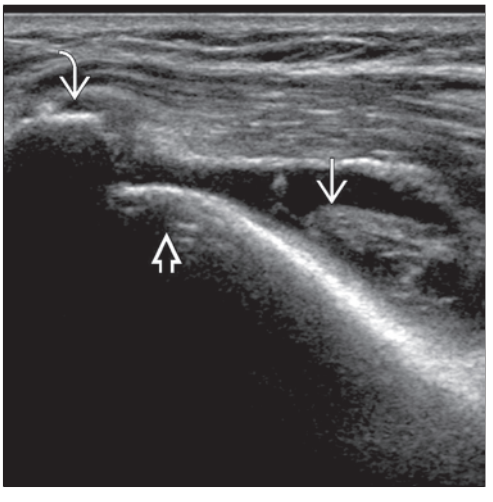


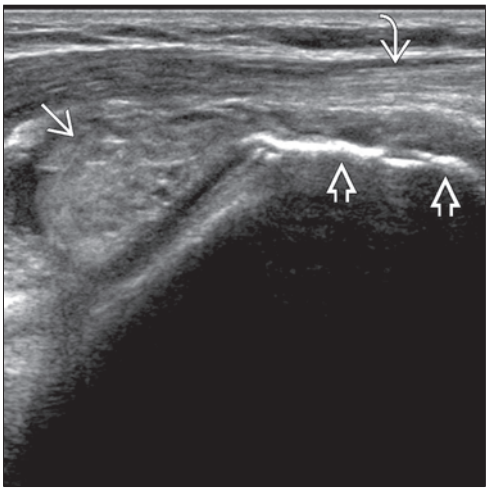
(Left) *Longitudinal ultrasound shows a small partial thickness tear at the articular surface of the supraspinatus tendon. Note the mild supraspinatus tendinosis.* ***(Right)*** *Longitudinal ultrasound shows moderate supraspinatus tendinosis with a complete avulsive-type tear from the insertional area. There is moderate subacromial-subdeltoid bursal distension containing some echogenic material consistent with hemorrhage. All of the anterior to midfibers of the supraspinatus tendon have been torn.*

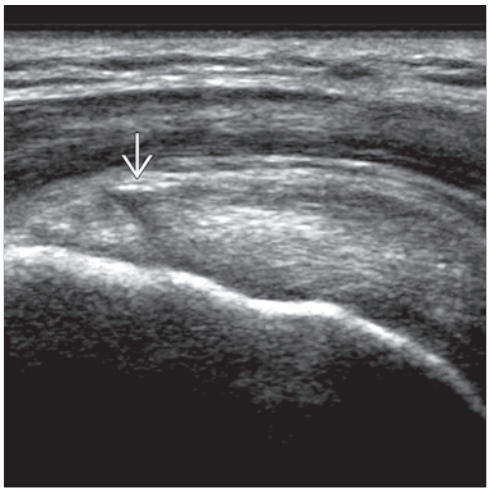


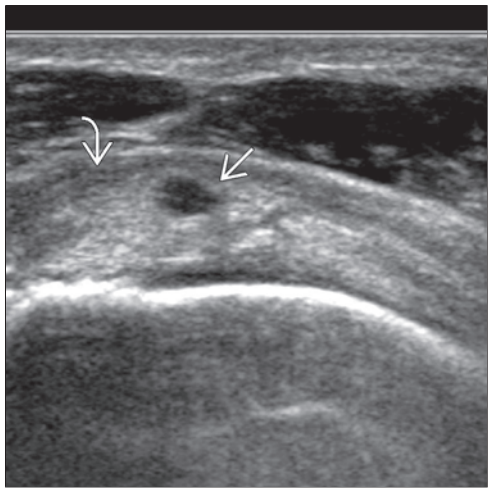


(Left) *Longitudinal ultrasound shows a complete tear of the supraspinatus tendon. The torn tendon end is retracted proximally. The humeral head has superiorly migrated and now lies close to the acromion.* ***(Right)*** *Transverse ultrasound of the same patient shows the subacromial-subdeltoid bursa distended with hemorrhagic clot. The superior facet of the greater tuberosity is bare due to a complete supraspinatus tendon tear and lies close to the moderately atrophic deltoid muscle.*



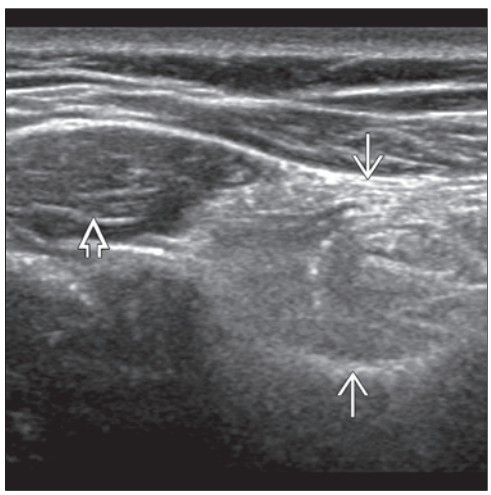




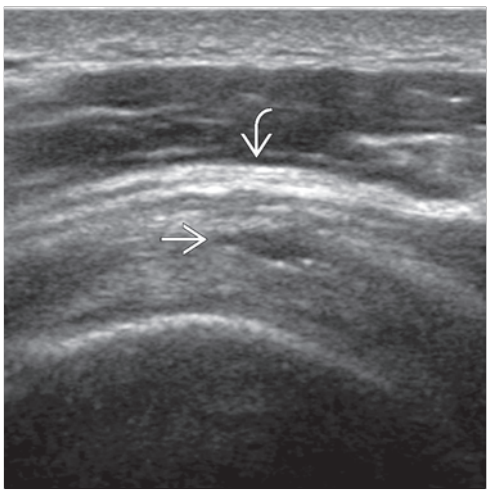


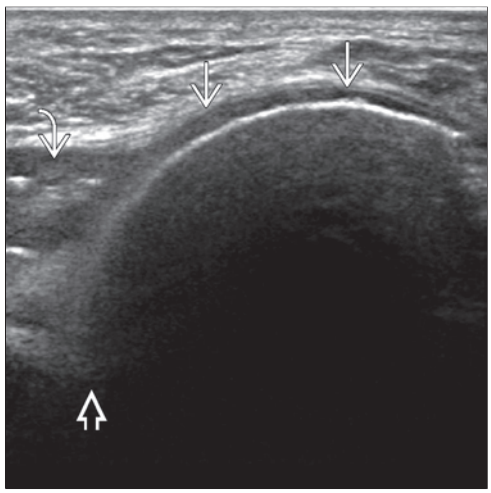
(Left) *Longitudinal ultrasound shows a well-defined hypoechoic bursal surface tear* ➔ *overlying the insertional area of the supraspinatus tendon. No bursal fluid is present.* ***(Right)*** *Transverse ultrasound shows a partial thickness intrasubstance tear* ➔ *of the anterior fibers of the supraspinatus tendon. As the bursal surface of the tendon is intact, this tear will not be visible at arthroscopy. Note the presence of mild to moderate background supraspinatus tendinosis* ➔.





(Left) *Clinical photograph of patient with rotator cuff tear shows muscle wasting at supraspinatus* ➔ *and infraspinatus* ➔ *muscle areas. Muscle atrophy is more readily appreciated in thin patients.* ***(Right)*** *Longitudinal ultrasound shows fatty atrophy of the infraspinatus muscle* ➔ *in a patient with rotator cuff tear. Note the hyperechoic infraspinatus fatty muscle atrophy with a depressed muscle contour due to volume loss compared to the normal appearance of the teres minor muscle* ➔.

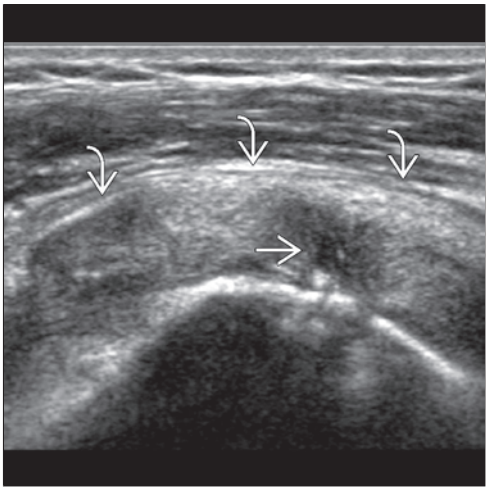


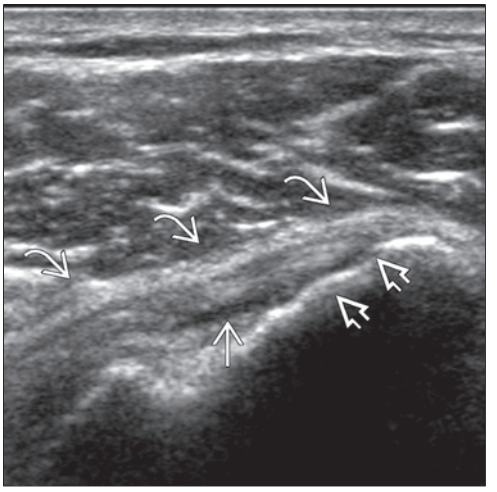


(Left) *Longitudinal ultrasound shows a partial intrasubstance tear* ➔ *involving 25% of the infraspinatus tendon thickness close to the myotendinous junction. This tear would not be seen on arthroscopy. Peribursal fat is located more superficially* ➔. ***(Right)*** *Longitudinal ultrasound shows a complete tear of the infraspinatus tendon. Torn infraspinatus fibers* ➔ *are retracted to the glenohumeral joint area* ➔. *Note clear visualization of the articular cartilage* ➔ *of the humeral head.*

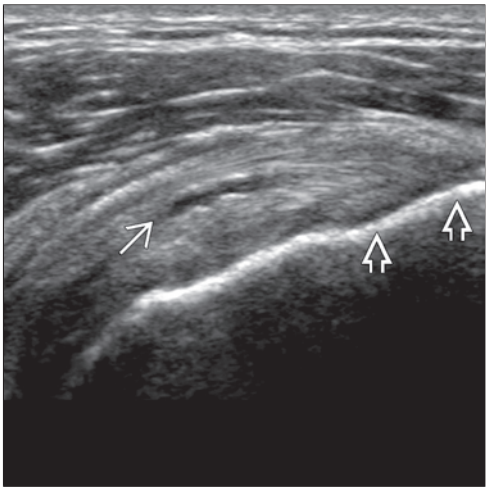
ROTATOR CUFF/BICEPS TENDON TEAR

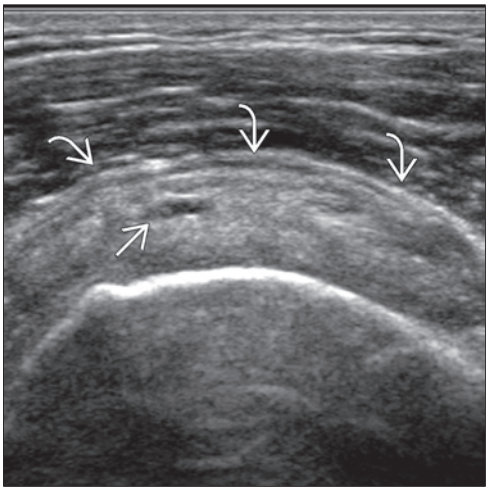
(Left) *Transverse ultrasound shows a partial thickness articular surface tear of the subscapularis tendon. Note moderate background tendinosis of the subscapularis tendon with tendon thickening and heterogenicity.* ***(Right)*** *Longitudinal ultrasound shows an avulsive-type tear of the moderately attenuated subscapularis tendon at insertional area at lesser tuberosity. The tear did not extend to superior edge of the subscapularis tendon and hence would not be visible on arthroscopy.*



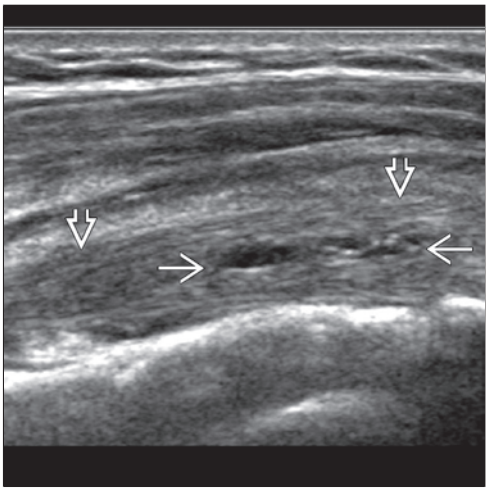


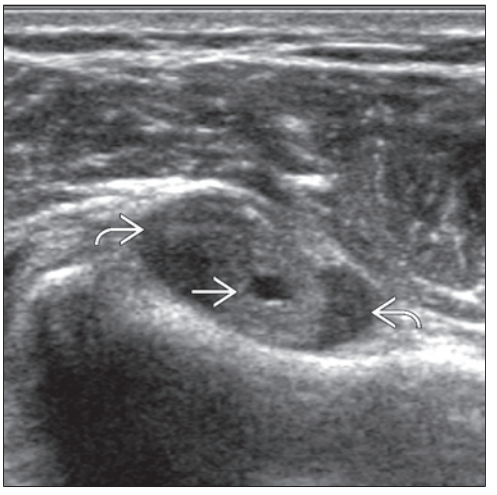
(Left) *Longitudinal ultrasound shows moderate tendinosis of the subscapularis tendon with an intrasubstance tear just proximal to the insertional area.* ***(Right)*** *Transverse ultrasound of the same patient shows a small intrasubstance tear within the more superior fibers of the subscapularis tendon. Mild to moderate subscapularis tendinosis is present.*

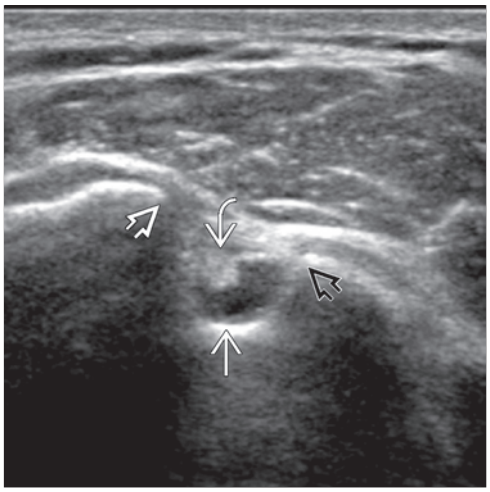


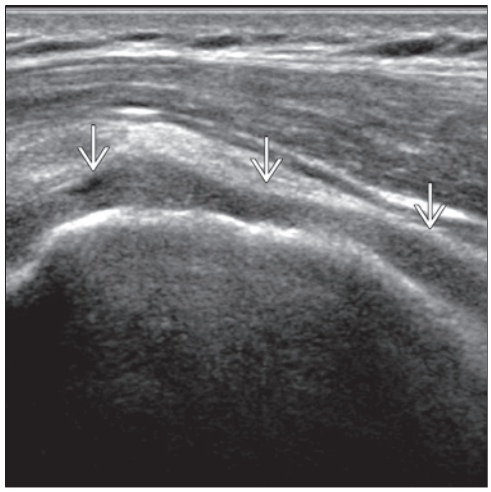


(Left) *Longitudinal ultrasound shows moderate biceps tendinosis with an irregular longitudinal split-like intrasubstance tear.* ***(Right)*** *Transverse ultrasound of the same patient shows an intrasubstance transverse tear within the biceps tendon. Moderate biceps tendinosis is present with mild synovial proliferation within the surrounding tendon sheath.*



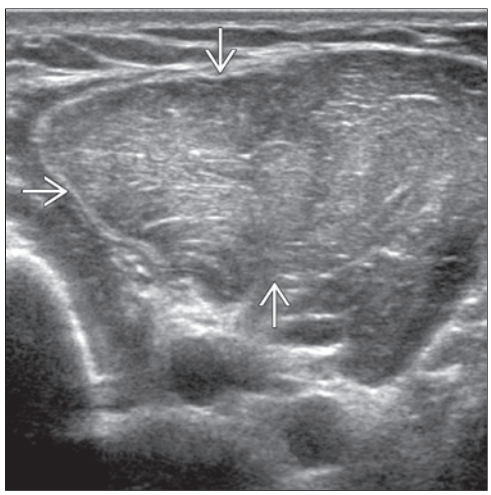




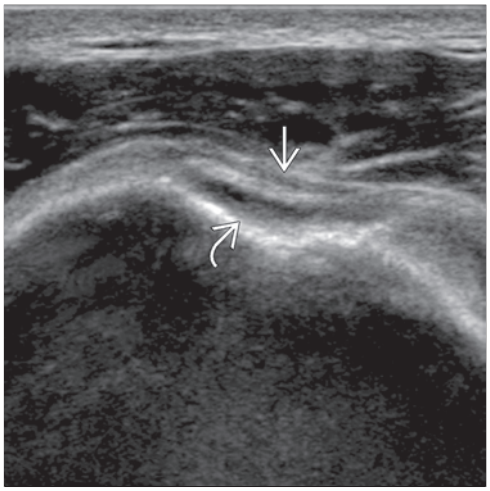


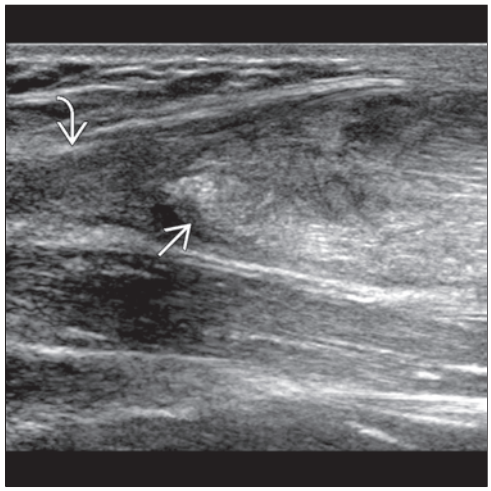
(Left) *Transverse ultrasound shows an empty bicipital groove* ➔ *with no visible long head of the biceps. The small echogenic structure* ➔ *within the tendon groove is most likely a remnant of the collapsed tendon sheath. Note the normal lateral* ➔ *and medial lips* ➔ *of the deep bicipital groove.* ***(Right)*** *Longitudinal ultrasound of the same patient shows complete rupture of the long head of the biceps tendon. There is fluid within the bicipital groove* ➔, *but no tendon is present.*





(Left) *Clinical photograph of the same patient shows a roundish swelling on the flexor aspect of arm, which became more noticeable with attempted biceps contraction. This swelling is due to the retracted biceps muscle belly ("Popeye" sign).* ***(Right)*** *Transverse ultrasound of the arm of the same patient shows a retracted bulbous long head of biceps muscle belly* ➔. *This can be mistaken for a soft tissue mass if one is not aware that the long head of the biceps has torn.*





(Left) *Transverse ultrasound shows a complete rupture of the long head of the biceps tendon. There are no tendon fibers within the bicipital groove* ➔. *Some fibers of the subscapularis tendon transverse the groove as the transverse ligament* ➔ *to insert onto the lateral lip of the bicipital groove are seen.* ***(Right)*** *Longitudinal ultrasound shows a retracted myotendinous junction* ➔ *of the long head of the biceps due to a complete tendon tear. The tendon sheath* ➔ *located proximally seems to contain blood.*

NON-ROTATOR CUFF TENDINOSIS

Key Facts

Terminology

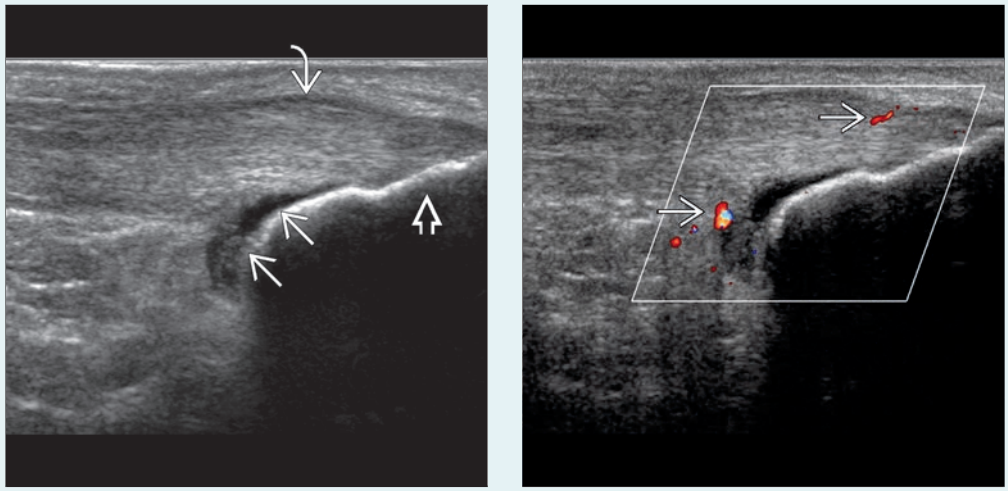
- Tendinosis: Degenerative disease of tendon with variable degree of peritendinitis

Imaging

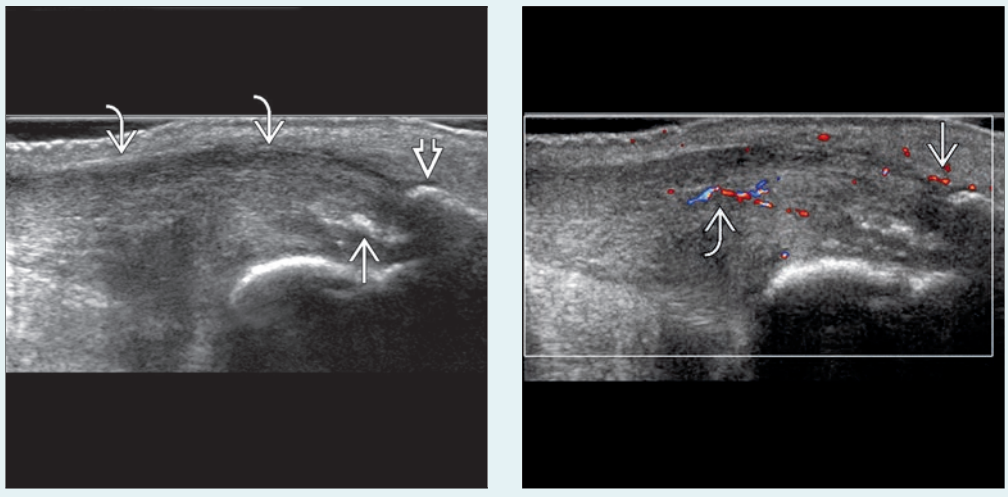
- Some tendons (Achilles, patellar, posterior tibialis, rotator cuff, biceps, common extensor tendon origin elbow, 1st extensor compartment wrist) are particularly susceptible to tendinosis
- Focal, diffuse, or nodular tendon enlargement with hypoechogenicity & progressive loss of normal fibrillar pattern
- Level of hyperemia correlates with disease activity
- Tendinosis predisposes to tendon tears (tears uncommon in tendons not affected by tendinosis)
- Partial tears are seen as sharp, linear, hypoechoic defects within area of tendinosis
  - Usually split tears
  - Should not be confused with dilated vascular channels within hyperemic tendon
- Variable peritendinitis: Swelling, edema, & hyperemia of tissues around tendon
  - Peritendinitis is important feature to assess as it will respond to anti-inflammatory medication
- Additional secondary signs
  - Tendon calcification
  - Tendon sheath effusion
  - Bursitis
  - Cortical erosion or hyperostosis at insertional area

Diagnostic Checklist

- Grade level of tendinosis & peritendinitis as mild, moderate, or severe
- Routinely examine with color Doppler imaging
- Be careful about using contralateral asymptomatic side as normal reference as subclinical tendinosis is common



(Left) *Longitudinal ultrasound of distal portion of Achilles tendon shows moderate diffuse thickening close to insertion into the calcaneum consistent with moderate insertional tendinosis. The tendon is heterogeneous & slightly hypoechoic in appearance. Note associated mild distension of the retrocalcaneal bursa. There is no calcaneal surface irregularity.* ***(Right)*** *Longitudinal color Doppler ultrasound of the same area shows mild hyperemia of the tendon. Only mild activity is present.*



(Left) *Longitudinal ultrasound of the distal portion of the Achilles tendon shows diffuse severe thickening with tendon hypoechogenicity. Small foci of dystrophic calcification are present. Prominent calcaneal surface irregularity & spur are also present.* ***(Right)*** *Longitudinal color Doppler ultrasound of the same area shows moderate hyperemia within the tendon. Mild peritendinous hyperemia is also present close to the insertion.*

NON-ROTATOR CUFF TENDINOSIS

TERMINOLOGY

Synonyms
- Tendinosis or tendinopathy

Definitions
- Primarily a disease of tendon with variable degree of peritendinitis
  - Peritendinitis is inflammation of soft tissues surrounding tendon
- Collagenous tendon degeneration with proteoglycan deposition

IMAGING

General Features
- Best diagnostic clue
  - Focal, diffuse, or nodular tendon enlargement with loss of normal fibrillar echotexture
- Location
  - Some tendons are more susceptible to tendinosis
    - Rotator cuff and biceps tendons
    - Achilles: Calcaneal insertion > mid portion of tendon
    - Patellar: Proximal > distal; deep > superficial
    - Posterior tibialis: Insertion > retro- or inframalleolar areas
    - Common extensor tendon origin of elbow
    - Gluteus minimus and medius insertion at greater trochanter
    - Ischial attachment of hamstring tendons
  - Susceptible areas
    - Tendon insertion or areas where tendons curve (e.g., biceps tendon at cephalad end of bicipital groove)
- Morphology
  - Anterior convexity of mid 1/3 of Achilles tendon
  - Normal cross-sectional area of Achilles tendon
    - 0.54 ± 0.11 cm^2 at soleus musculotendinous junction; 0.54 ± 0.12 cm^2 at midlevel; 0.74 ± 0.15 cm^2 at calcaneal insertion
  - Normal size of posterior tibialis tendon
    - ~ 2x size of flexor digitorum longus tendon
    - < 0.16 cm^2 at retromalleolar; < 0.18 cm^2 at inframalleolar; < 0.27 cm^2 at insertion
  - Peroneus longus tendon is normally slightly larger than peroneus brevis tendon

Ultrasonographic Findings
- Increased tendon thickening with hypoechogenicity & progressive loss of normal fibrillar pattern
  - Cross-sectional area of tendon measured at specific locations
    - Useful for follow-up rather than diagnosis; abnormal appearance takes a long time to change
- Proteoglycan accumulation: Focal hypoechoic area within tendon that may bulge beyond tendon margins
- Hyperemia within or around tendon is a common feature
  - Level of hyperemia correlates with disease activity
- Partial tears seen as sharp linear hypoechoic defect within area of tendinosis
  - Occur with moderate to severe degrees of tendinosis; usually run longitudinally in tendon (split tears)
  - May be difficult to distinguish from areas of focal proteoglycan deposition
    - Tears tend to be more linear & hypoechoic
  - Should not be confused with dilated vascular channels within hyperemic tendon (use color Doppler ultrasound)
- Avulsive-type tears at tendon insertional area
  - Tendon stripped (usually partially) from insertional area
- Secondary signs of tendinosis are more common in moderate to severe tendinosis
  - Tendon sheath effusion (if tendon sheath is present)
  - Dystrophic calcification within area of tendinosis (particularly for Achilles & patellar tendons)
  - Reactive cortical erosion or hyperostosis at insertional area
  - Marrow edema not seen with US (seen with MR)
  - Adjacent bursitis (Achilles, common extensor)
  - Paratenonitis (Achilles, patella)
- Secondary signs that are commonly seen in normal asymptomatic subjects
  - Focal calcification of Achilles tendon in 21% of normal subjects
  - Fluid in retrocalcaneal bursa in 35% of normal subjects
  - Calcaneal bony contour abnormality in 63% of normal subjects
- Variable peritendinitis of surrounding soft tissues
  - Seen as swelling, edema, & hyperemia on color Doppler imaging
  - Grade as mild, moderate, or severe
  - Peritendinitis important feature to note as it will respond to anti-inflammatory medication
  - Tendinosis per se does not have inflammatory component
- Elastography to diagnose & grade tendinosis
  - Shows promise in early diagnosis of tendinosis before grayscale features become apparent

Radiographic Findings
- Radiography
  - Sclerosis, cortical irregularity, hyperostosis of insertional tendinosis
  - Intratendinous dystrophic calcification
  - Accessory navicular bone associated with posterior tibialis tendinosis

MR Findings
- Increased T1W, T2W signal within enlarged tendon
- Hyperintense inflammatory fluid around tendon
- Partial tears hyperintense on FS PD FSE or STIR images
- Reactive marrow change

Imaging Recommendations
- Best imaging tool
  - Ultrasound as nearly all tendons are readily accessible
- Protocol advice
  - Examine both symptomatic & contralateral side
    - Be careful about using asymptomatic contralateral side as a normal standard as subclinical tendinosis is common
    - Always evaluate level of peritendinitis
  - Use minimal transducer pressure to avoid blanching color Doppler signal

NON-ROTATOR CUFF TENDINOSIS

DIFFERENTIAL DIAGNOSIS

Xanthoma
- Affects Achilles > patellar tendon
- Affected areas tend to be more nodular & less hyperemic than tendinosis
- Features of severe hypercholesterolemia
  - ± thickening of extensor tendon hoods over metacarpophalangeal joints

Tenosynovitis
- Primarily a disease of tendon sheath
- Affects tendon with complete synovial sheath
- Synovial inflammation rather than tendon thickening predominates
- Often may get elements of tenosynovitis & tendinosis coexisting

PATHOLOGY

General Features
- Etiology
  - Repetitive overuse → microtrauma with collagen bundle microfracture & incomplete healing
  - Achilles: Hypovascular watershed zone 2-6 cm proximal to calcaneal insertion
    - Eccentric loading of fatigued muscle-tendon unit or overtraining
    - Runners susceptible to acceleration (sprinting) & deceleration (eccentric contraction) injuries
  - Posterior tibialis: Flatfoot & accessory navicular bone
    - Thickening of spring ligament (superior calcaneonavicular portion) visible on ultrasound
  - Patellar tendon: Running & jumping
    - Microtrauma between patellar bone tip & central deep fibers of adjacent patellar tendon
- Relevant anatomy
  - Achilles & patellar tendons have incomplete synovial sheath
- Posterior tibialis inserts into accessory navicular bone (when present), medial pole of navicular bone, & cuneiform bones
  - Cornuate navicular is elongated medial pole of navicular bone

Gross Pathologic & Surgical Features
- Tendon is gray instead of glistening white
- Nodular thickening, calcification, & partial tendon tears
- Inflamed tissues around tendon

Microscopic Features
- Features of failed healing response
  - Noninflammatory intratendinous collagen degeneration
  - Fiber degeneration (fibrinoid, mucoid) & thinning with partial tears
  - Hypercellularity with scattered vascular ingrowth
  - Increased interfibrillar glycosaminoglycans (chondroitin sulfate)
- Inflammation of peritendinous tissues

CLINICAL ISSUES

Presentation
- Most common signs/symptoms
  - Pain with stretching of tendon
- Other signs/symptoms
  - Tendinosis is often visible on ultrasound with minimal or no symptoms (subclinical)
    - Subclinical disease is common on contralateral side in patients with unilateral symptoms
- Clinical profile
  - Chronic dull to sharp pain at onset of exercise
    - Gradually subsides with more exercise & returns following cessation of exercise

Demographics
- Age
  - Young middle-aged adults (most common), young athletes, & older sedentary populations
- Epidemiology
  - Usually associated with either physical or physiological overuse
  - Initial injury not rested sufficiently

Natural History & Prognosis
- Severe ultrasound features bode for chronic relapsing & remitting symptomatology
- Minimal to mild ultrasound features bode for a favorable outcome with conservative treatment
- Tendinosis predisposes to both partial & complete tendon tears
  - Tears uncommon in normal tendons
  - Tendinosis (primarily a disease of tendon) predisposes to tendon tears much more than tenosynovitis (primarily a disease of tendon sheath)

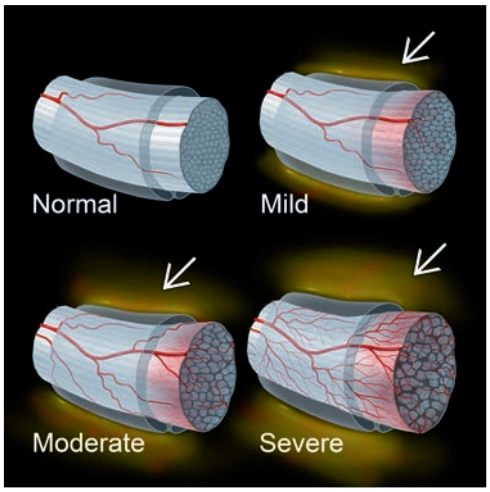
Treatment
- Conservative
  - Rest & immobilization
  - Controlled, slow stretching exercise or cross-training/alternative exercise
  - Anti-inflammatory medication if peritendinitis
- Nonconservative
  - Ultrasound-guided dry needling, blood or platelet-rich plasma (PRP) injection, barbotage, sclerotherapy
  - Ultrasound-guided steroid injection for peritendinitis
  - Focal proteoglycan accumulation treated with debridement
  - Suturing of large partial tears

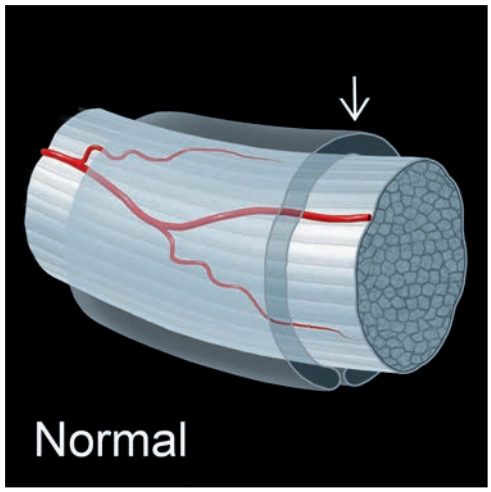
DIAGNOSTIC CHECKLIST

Consider
- Grade tendinosis as mild, moderate, or severe
- Grade peritendinitis as mild, moderate, or severe
- Routinely examine with color Doppler imaging
- Look for secondary features & partial tears
- Measurement of tendon caliber is useful for follow-up

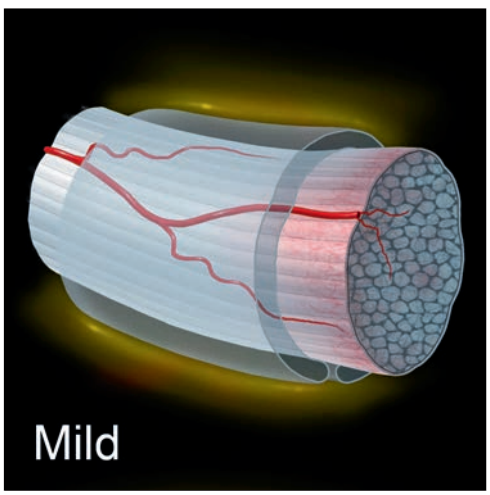
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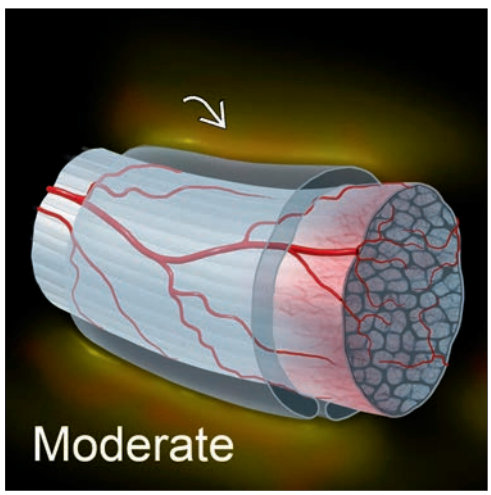
1. Leung JL et al: Sonography of chronic Achilles tendinopathy: a case-control study. J Clin Ultrasound. 36(1):27-32, 2008



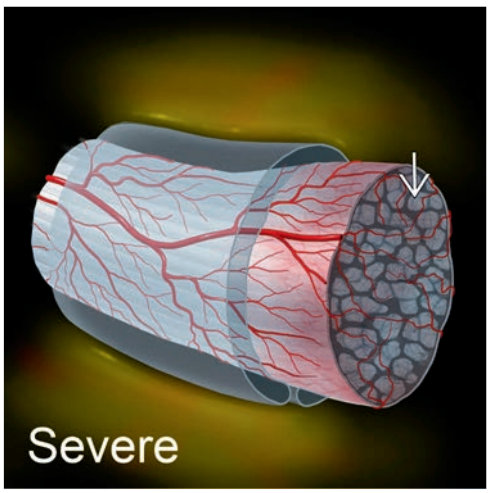


(Left) *Graphic shows grades of tendinosis. The severity of tendinosis and degree of surrounding peritendinitis* ➔ *should be independently graded. The more severe the tendinosis, the greater the likelihood of tendon tear. The more severe the peritendinitis, the greater the likelihood of clinical response to anti-inflammatory medication.* ***(Right)*** *Graphic shows normal tendon structure with tendon sheath* ➔ *shown for illustrative purposes. Most tendons do not have a tendon sheath.*





(Left) *Graphic shows mild tendinosis with mild tendon swelling (due to proteoglycan accumulation) and mild tendon hyperemia. Intrinsic vascularity is not a feature of normal tendons.* ***(Right)*** *Moderate tendinosis with more severe tendon swelling, proteoglycan deposition, and tendon hyperemia is shown. Although tendinosis and peritendinitis (seen as peritendinous edema and hyperemia)* ➔ *severity are broadly interrelated, both features should be independently graded as mild, moderate, or severe.*

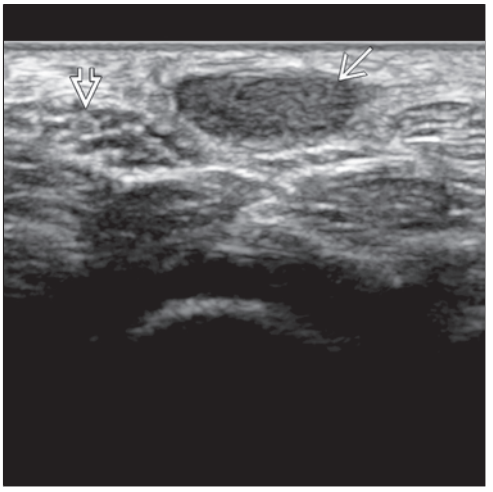


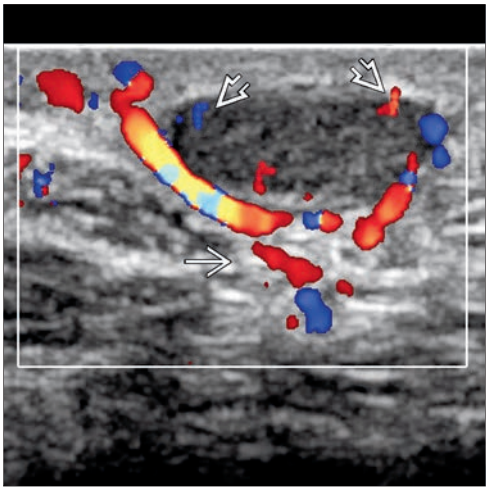


(Left) *Graphic shows severe tendinosis with more severe tendon swelling and tendon hyperemia* ➔ *(manifest on US as tendon swelling, tendon hypoechogenicity, loss of fibrillar echopattern, and increasing intratendinous hyperemia). Mild tendon sheath swelling is often seen and is a feature of peritendinitis rather than a primary tendon sheath inflammation.* ***(Right)*** *Longitudinal US of palmaris longus tendon shows how tendinosis is often localized to that part of a tendon* ➔ *under most physical stress.*

NON-ROTATOR CUFF TENDINOSIS

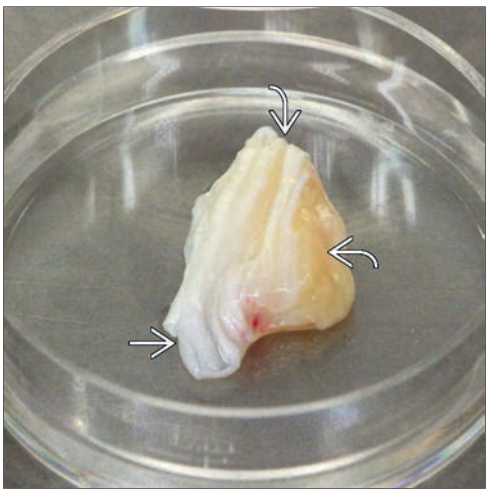
(Left) *Transverse ultrasound in the same patient shows moderate severity palmaris longus tendinosis* ➔ *with tendon thickening, hypoechogenicity, and loss of the normal fibrillar pattern. The adjacent median nerve* ➔ *is mildly indented.* ***(Right)*** *Transverse color Doppler ultrasound shows moderate peritendinous* ➔ *and mild intrinsic hyperemia* ➔ *(reflective of disease activity). The overall appearances are those of moderate-severity palmaris longus tendinosis with moderate peritendinitis and mild disease activity.*



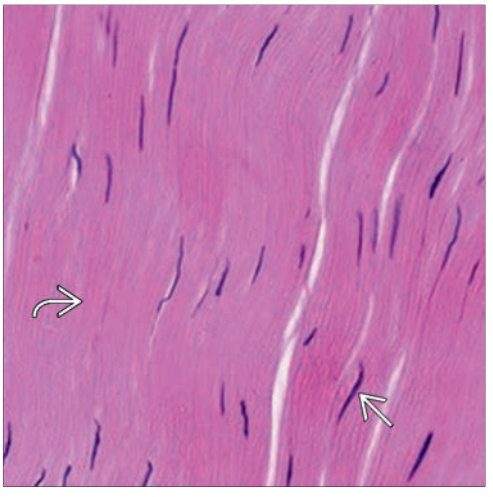


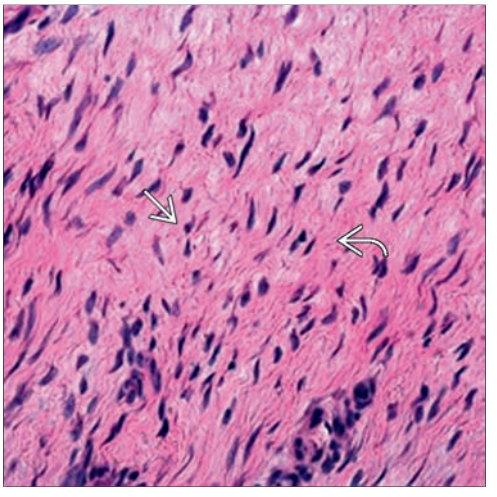
(Left) *Photograph shows tendon remnant* ➔ *trimmed from normal semitendinosus tendon graft prior to anterior cruciate ligament reconstruction. Normal healthy tendon has a glistening white appearance. (Courtesy C. KM, MD.)* ***(Right)*** *Photograph shows section of patellar tendon excised from patient with chronic patellar tendinosis. Compared to the healthy part of the patellar tendon* ➔*, the area of patellar tendinosis* ➔*, located proximally and deep, is thickened with yellowish tissue. (Courtesy C. KM, MD.)*

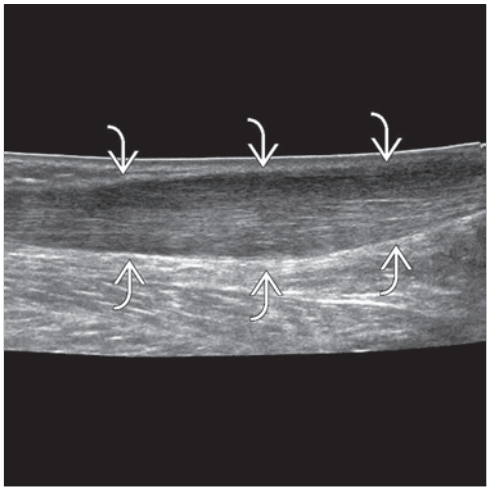


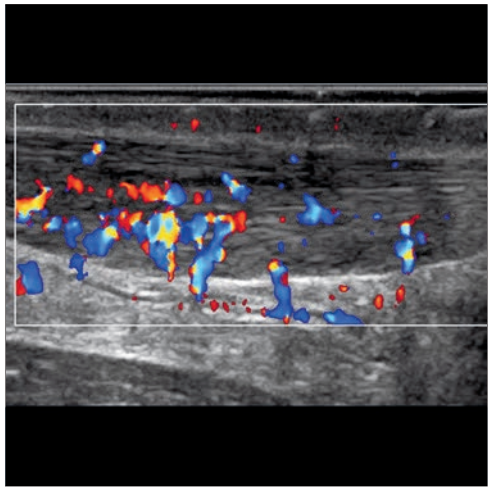


(Left) *Histological section (40x, hematoxylin & eosin stain) of normal tendon shows normal densely packed collagen fibers* ➔ *with normal looking slender tenocyte nuclei* ➔*. (Courtesy C. KM, MD.)* ***(Right)*** *Histological section (40X, hematoxylin & eosin stain) of tendinosis area shows severe tissue hypercellularity with more rounded, plump nuclei* ➔ *and disorganization of the less tightly packed collagen fibers* ➔*. Specific staining (safranin O/fast green) is required to assess proteoglycan content. (Courtesy C. KM, MD.)*

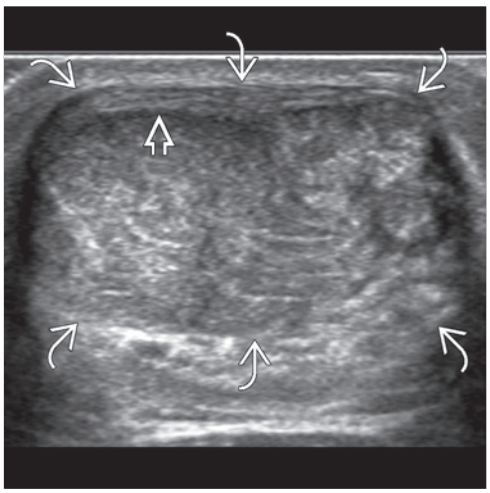


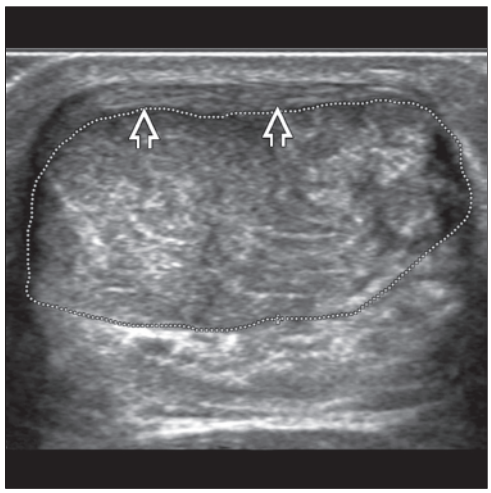




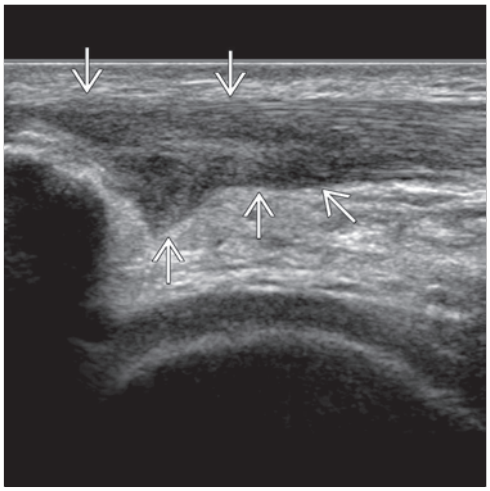


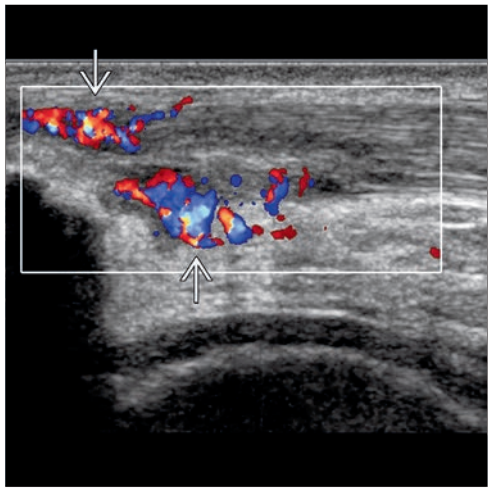
(Left) *Longitudinal ultrasound of the midportion of the Achilles tendon shows moderate diffuse thickening & mild hypoechogenicity. No tear or calcification is present.* ***(Right)*** *Longitudinal color Doppler ultrasound of the same area shows severe intratendinous & peritendinous hyperemia consistent with severe disease activity.*





(Left) *Transverse ultrasound of the Achilles tendon shows a severely thickened tendon with heterogeneous echogenicity indicative of tendinosis. Moderate paratenon thickening is present.* ***(Right)*** *Transverse ultrasound of the same area shows continuous trace to measure the cross-sectional area of the tendon (dotted lines). Note that the paratenon thickening is not included in this measurement. Tendon caliber measurement is good for follow-up but not necessary for diagnosis.*

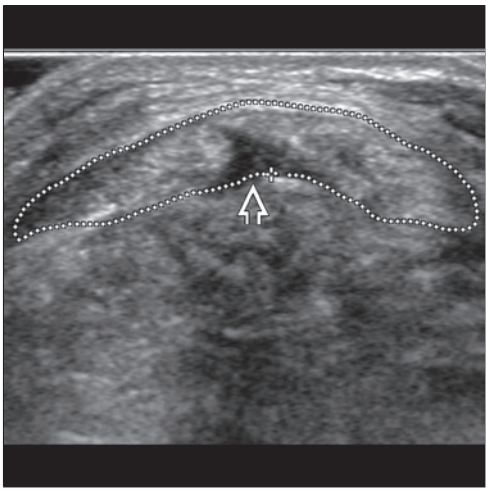




(Left) *Longitudinal ultrasound of a patellar tendon shows a severely thickened & heterogeneous hypoechoic tendon with loss of normal fibrillar pattern, particularly of the deep fibers. There is no associated tendon calcification. Features are consistent with severe tendinosis.* ***(Right)*** *Longitudinal ultrasound of the same area shows severe intratendinous hyperemia, particularly of the deep fibers. This is consistent with severe disease activity.*

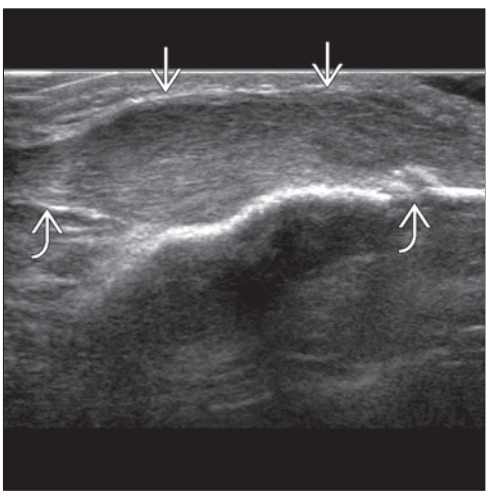
NON-ROTATOR CUFF TENDINOSIS

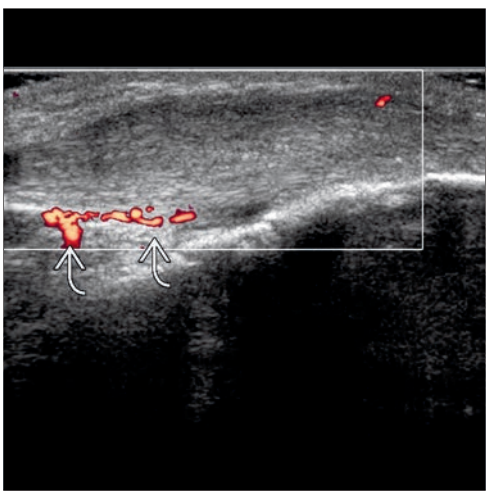
(Left) *Transverse ultrasound shows a cross-sectional area measurement of a slightly thickened proximal patellar tendon (dotted lines). There is a discrete area of proteoglycan accumulation centrally* ➔. ***(Right)*** *Longitudinal panoramic ultrasound view of a patellar tendon shows diffuse thickening, particularly of the midportion* ➔. *The whole tendon is more hypoechoic than usual.*



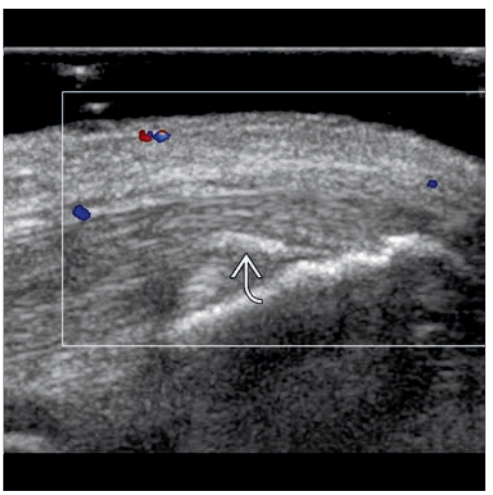


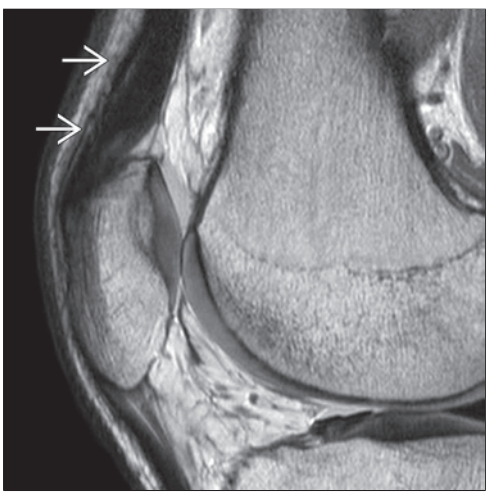
(Left) *Longitudinal ultrasound of a patellar tendon close to the tibial insertion shows severe focal thickening with hypoechogenicity & loss of normal fibrillar pattern* ➔ *consistent with severe tendinosis. Mild cortical irregularity is present* ➔. ***(Right)*** *Longitudinal power Doppler ultrasound at the same location shows peritendinous hyperemia* ➔ *consistent with inflammation.*



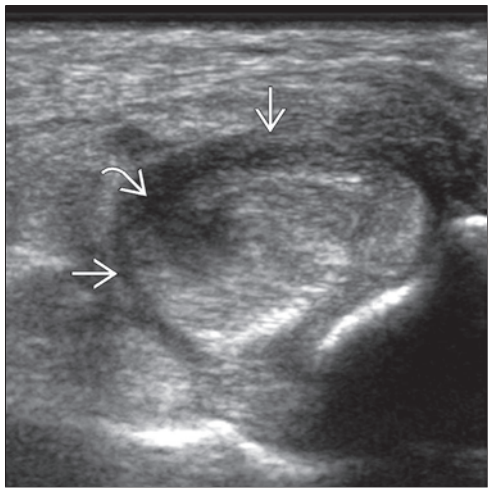


(Left) *Longitudinal color Doppler ultrasound of a quadriceps tendon shows mild thickening at the patellar insertion. Mild intrasubstance dystrophic calcification is present* ➔. *There is no significant hyperemia present, which indicates quiescent disease.* ***(Right)*** *Sagittal proton-density MR of the knee in the same patient shows a moderately thickened quadriceps tendon* ➔ *with minimal increased tendon signal intensity corresponding to the ultrasound findings of tendinosis.*

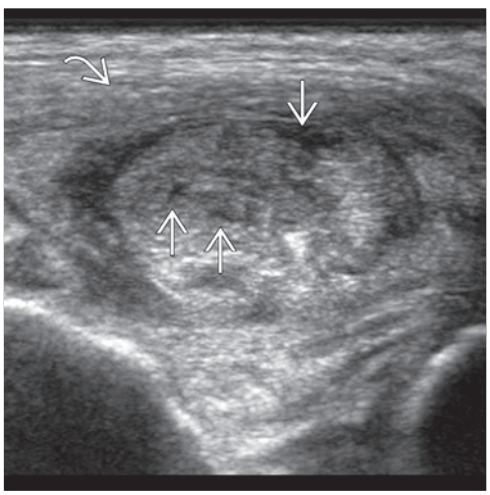


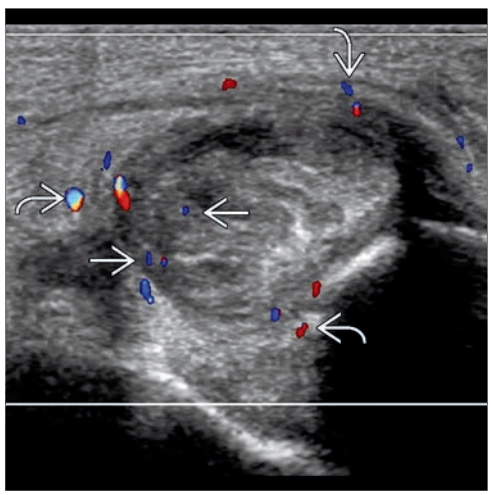




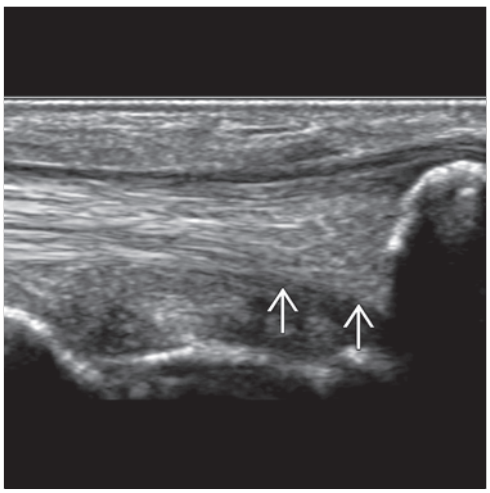


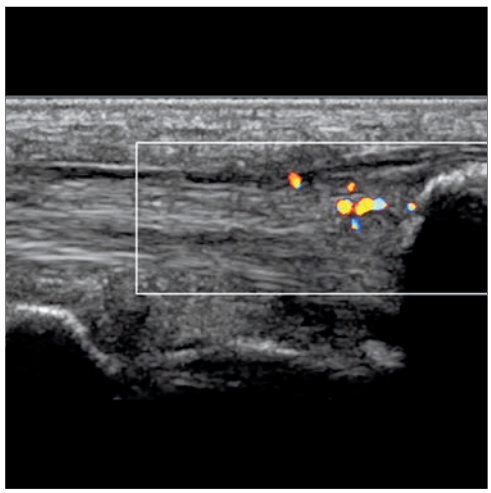
(Left) *Clinical photo shows a patient who presented with flat foot for 1 year. There is collapse of the longitudinal arches with moderate heel valgus deformity. Abnormal stresses are placed on the medial side of the ankle & foot.* ***(Right)*** *Transverse ultrasound of the retromalleolar tibialis posterior tendon in the same patient shows severe tendinosis with a thickened heterogeneous tendon. A small hypoechoic area with ill-defined margin is consistent with an area of proteoglycan accumulation.*





(Left) *Transverse ultrasound of the same tibialis posterior tendon at the inframalleolar level shows severe tendinosis with severe small hypoechoic areas consistent with small intrasubstance tears. There is moderate thickening of the overlying flexor retinaculum.* ***(Right)*** *Transverse color Doppler ultrasound at the same location shows moderate intratendinous & peritendinous hyperemia consistent with moderate disease activity & moderate peritendinitis.*

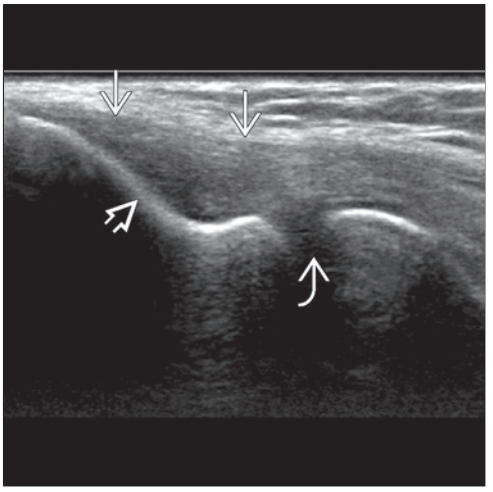


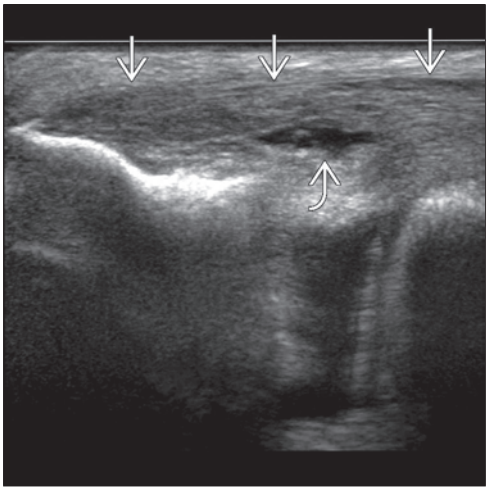


(Left) *Longitudinal ultrasound of the tibialis tendon at the navicular bone insertion shows mild focal tendon thickening. The normal tendon shows this degree of expansion at its insertion.* ***(Right)*** *Longitudinal color Doppler ultrasound at same location shows mild hyperemia within the tendon substance indicative of mild tendinosis. Normal tendons do not display flow on color Doppler imaging. Hyperemia helps confirm the presence of tendinosis.*

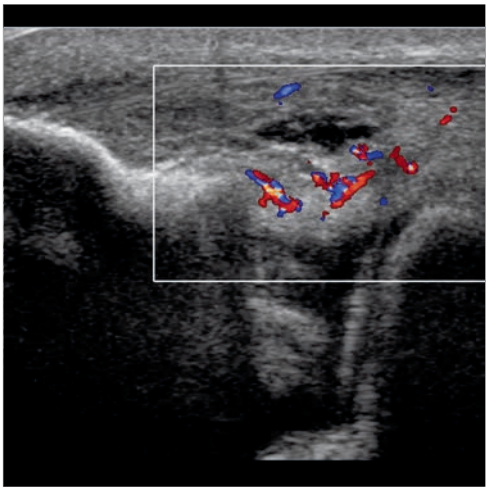
NON-ROTATOR CUFF TENDINOSIS

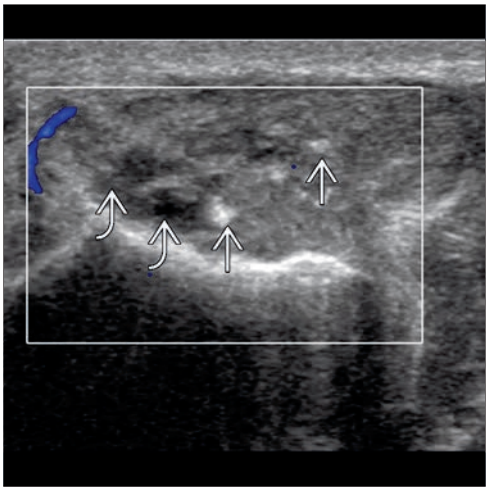
(Left) *Longitudinal ultrasound of an elbow shows normal common extensor tendon origin* ➔ *at the lateral epicondyle* ➔. *It is not thickened, with a normal fibrillar pattern & no calcification or tear. Note the tendons coursing over the radiohumeral articulation* ➔. ***(Right)*** *Longitudinal ultrasound of the contralateral abnormal common extensor tendon origin shows severe tendon thickening* ➔ *& an intrasubstance partial tear of the midfibers* ➔.



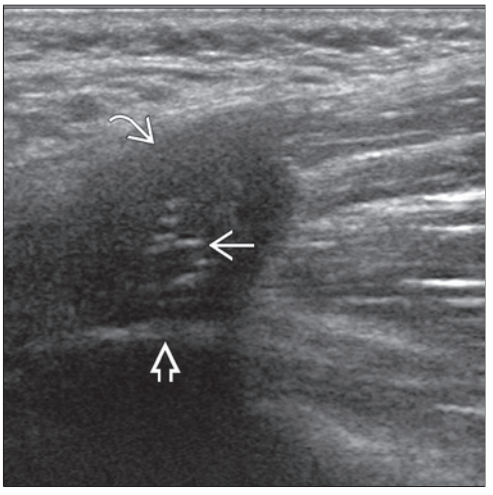


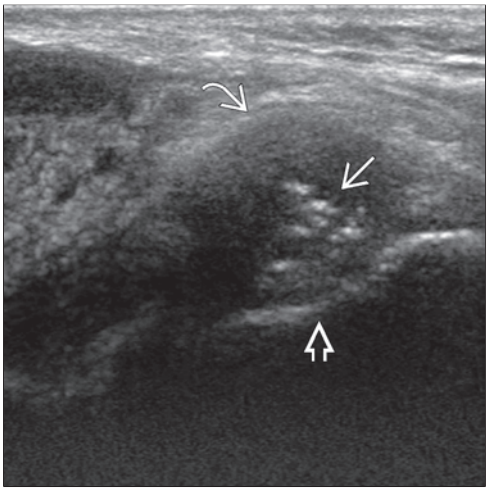
(Left) *Longitudinal color Doppler ultrasound of the same location shows severe hyperemia within the thickened tendon, consistent with severe disease activity.* ***(Right)*** *Transverse color Doppler ultrasound of another patient shows a severely thickened common extensor tendon origin with several small echogenic foci due to dystrophic calcification* ➔. *Small discrete tears are present at the insertion* ➔. *Minimal hyperemia is present.*

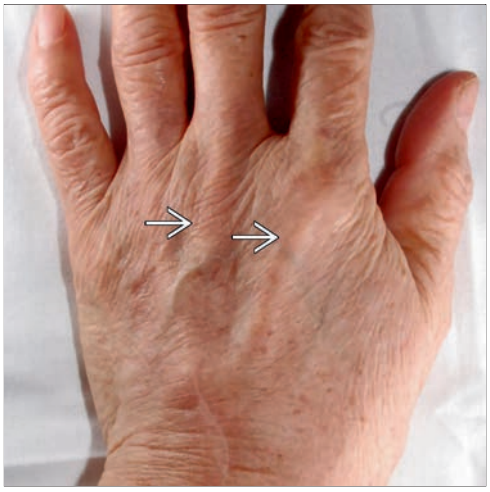


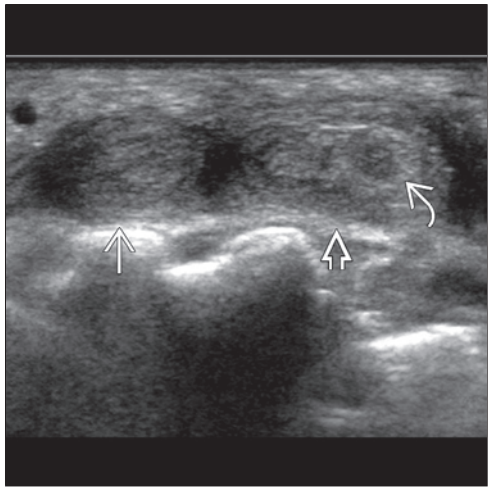


(Left) *Longitudinal ultrasound of adductor longus tendon shows multiple foci of tendon calcification* ➔ *close to the adductor longus origin at the pubic ramus* ➔. *The tendon* ➔ *is moderately swollen & hypoechoic, consistent with tendinosis.* ***(Right)*** *Transverse ultrasound at the same location as previous image shows a moderately thickened adductor longus tendon* ➔ *with foci of dystrophic calcification* ➔ *close to the pubic ramus* ➔.

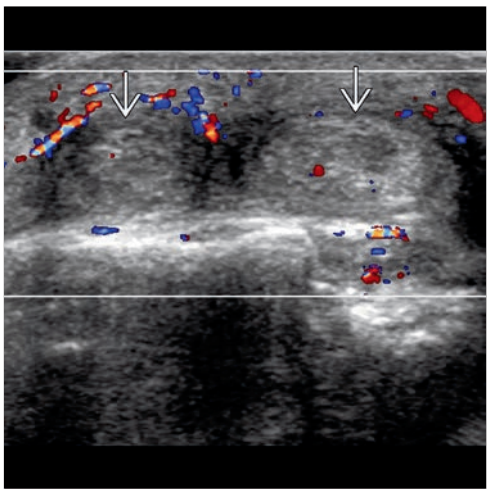


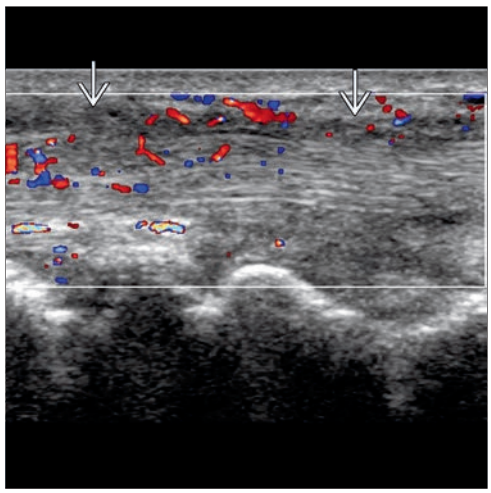




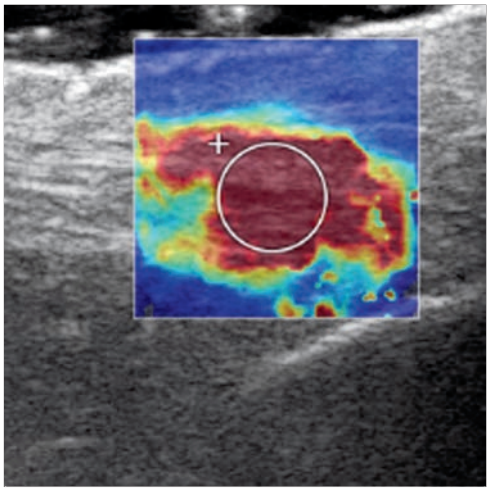


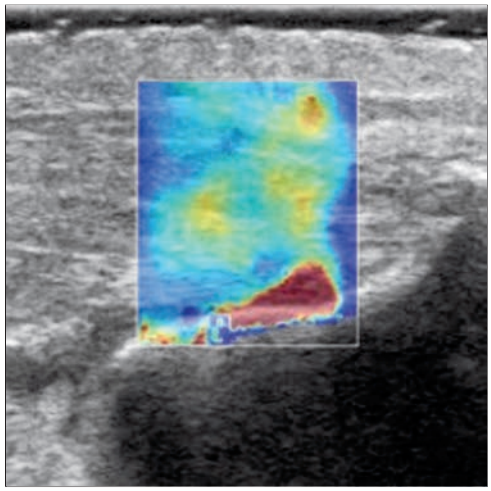
(Left) *Clinical photo shows a patient with dorsal hand pain & swelling. Note swelling of the extensor digitorum (ED) tendons to the middle & index fingers* ➔. ***(Right)*** *Transverse ultrasound of ED of the index* ➔ *& middle* ➔ *fingers (same patient) shows marked thickening of the tendons & loss of the normal fibrillar pattern. Note the focal hypoechoic area* ➔ *within the tendon, consistent with myxoid accumulation.*





(Left) *Transverse color Doppler ultrasound of the same patient shows moderate hyperemia around the thickened extensor digitorum tendons* ➔ *consistent with moderate peritendinitis. The tendon sheath is not present at this level.* ***(Right)*** *Longitudinal color Doppler ultrasound of the same location shows extensor digitorum tendon* ➔ *thickening with intratendinous hyperemia, consistent with moderate disease activity.*





(Left) *Longitudinal elastography shows the normal stiff appearance of the Achilles tendon at its insertion as indicated by the red color. The elasticity spectrum varies between red (hard tissue) & blue (soft tissue). The normal tendon is red in color.* ***(Right)*** *Longitudinal ultrasound elastography shows softening of the Achilles tendon at its insertion, compatible with severe tendinosis, as indicated by the blue coloring.*

NON-ROTATOR CUFF TENDON TEARS

Key Facts

Terminology
- Tendon tear = discontinuity in tendon fibers
  - Partial thickness, full thickness, or complete

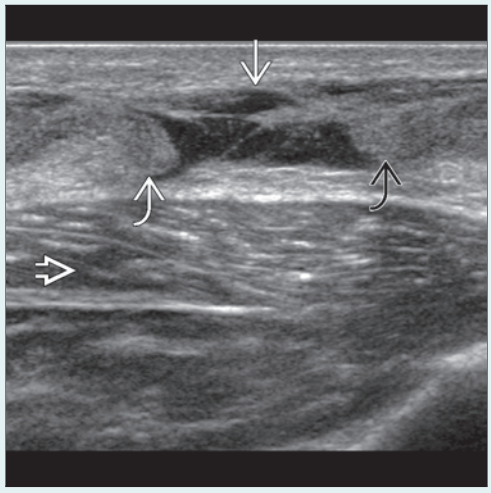
Imaging
- Occurrence of tendon tears mirrors that of tendinosis
  - Tendinosis is strong prerequisite of tendon tear
  - Tendon tears occur in those tendon areas prone to tendinosis
- Ultrasound diagnoses tendon tears with high accuracy and precision
- Gap within tendon is usually filled with anechoic or hypoechoic fluid
  - In acute phase, gap is filled with blood ± gas locules
- Traumatic tendon swelling impedes assessment of preexisting tendinosis
- Collapsed synovial sheath may be mistaken for attenuated tendon
- Ultrasound is accurate in detecting retear and defining cause of limited movement following repair
  - Limited movement may be due to tendon adhesions
  - Tendon swelling remains after tendon strength has returned
- For small tendons, examine first transversely along length of tendon
- Passive tendon movement helps in identifying tear

Top Differential Diagnoses
- Tenosynovitis
- Avulsion fracture

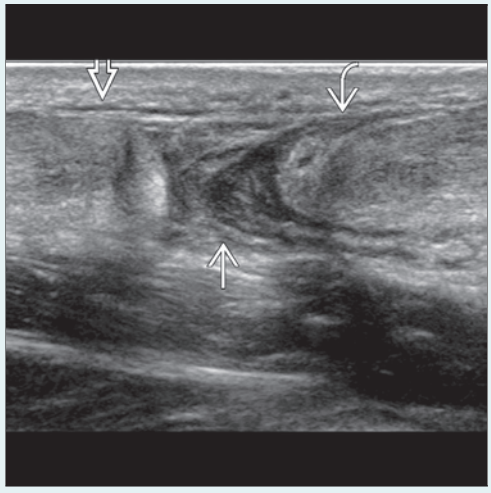
Diagnostic Checklist
- Examine entire length of tendon, looking for fluid-filled gap, empty tendon sheath, or focal depression of tendon surface

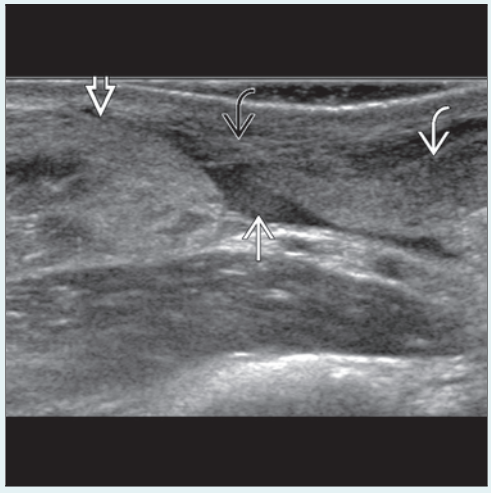
(Left) *Clinical photo shows both heels hanging freely over the edge of a bed with the patient lying prone. There is loss of plantar flexion on the affected left side with swelling ⇨ of the Achilles region.* ***(Right)*** *Longitudinal ultrasound of the same patient shows complete tear of the proximal 1/3 of the Achilles tendon ⇨. The proximal ⇨ and distal ⇨ stumps are retracted. The soleus muscle deep to the tear ⇨ is shown.*





(Left) *Longitudinal ultrasound of the distal leg shows a complete tear in the proximal 1/3 of the Achilles tendon with hematoma ⇨ partially filling the retraction gap. Note the swollen proximal ⇨ and distal ⇨ tendon ends.* ***(Right)*** *Longitudinal ultrasound from another patient shows complete Achilles tendon tear ⇨ just distal to the musculotendinous junction. The proximal ⇨ and distal ⇨ ends are retracted. The plantaris tendon ⇨ is intact.*





NON-ROTATOR CUFF TENDON TEARS

TERMINOLOGY

Synonyms
- Tendon rupture, tendon tear, tendon sprain, tendon strain
  - Tendon sprain and strain are clinical rather than imaging terms used to describe partial thickness tendon tears

Definitions
- Tendon tear = discontinuity in tendon fibers
  - Partial thickness tear: Part of the tendon thickness in one area of the tendon is torn
  - Full thickness tear: All of the tendon thickness in 1 area of the tendon is torn
  - Complete tear: Tendon is completely torn
  - High-grade partial tear: Partial tear involving > 50% of tendon fibers

IMAGING

General Features
- Best diagnostic clue
  - Fluid-filled gap in tendon
- Location
  - In most patients, occurrence and location of tendon tears closely mirror those of tendinosis
    - Tendinosis is strong prerequisite of tendon tear
    - Tendons and tendon areas prone to tendinosis are also prone to those tendon tears
      - Biceps tendon at upper end of bicipital groove
      - Common extensor tendon origin at lateral humeral epicondylar area
      - Extensor digitorum tendons dorsum of carpus
      - Extensor carpi ulnaris just distal to ulnar head
      - Hamstring tendons at ischial tuberosity
      - Adductor tendons at pelvic attachment
      - Gluteus medius and minimus tendons at greater trochanter
      - Quadriceps tendon just proximal to patella
      - Patellar tendon just distal to patella
      - Achilles tendon close to musculotendinous junction and at calcaneal insertion
      - Posterior tibialis tendon around medial malleolus or near insertion
      - Peroneal tendons around lateral malleolus, peroneal tubercle, or os peroneum (peroneus longus)
      - Tibialis anterior tendon close to insertion
- Morphology
  - Some tendons preferentially tear transversely
    - Adductor, quadriceps, patellar, Achilles, tibialis anterior, and wrist extensors and flexors
  - Some tendons preferentially tear longitudinally
    - Hamstrings, posterior tibialis, peroneal tendons, and biceps
  - Larger tendons tend to tear transversely, whereas smaller tendons tend to tear either longitudinally or transversely

Ultrasonographic Findings
- Fluid-filled gap within tendon
  - Gap usually filled with anechoic or hypoechoic fluid
  - In acute phase, gap may be filled with blood ± fat ± gas locules, making tendon ends difficult to see
    - Irregular tendon ends
- Often swollen tendon ends
  - Swelling helps improve visibility on ultrasound examination
  - Swollen finger tendon ends may give rise to ovoid-shaped mass in midpalm
- Collapsed synovial sheath may be mistaken for attenuated tendon
  - Applies to smaller tendons (i.e., finger flexors and biceps tendons)
- Partial tear
  - Focal discontinuity of tendon not involving all tendon fibers
  - Lack of complete tendon retraction is the most important feature to distinguish partial from complete tear
- Partial intrasubstance tear
  - Can be difficult to distinguish from focal areas of proteoglycan accumulation in tendinosis
    - Clinically, this distinction is not hugely relevant
  - Tear is linear, sharp, and more hypoechoic
  - Focal proteoglycan accumulation is rounder, more irregular, and less hypoechoic
- Traumatic tendon swelling
  - Can hinder evaluation of presence and severity of preexisting tendinosis
    - Intratendinous calcification and hyperemia are good clues to preexisting tendinosis
    - Ultrasound assessment of contralateral tendon may also help as comparable degree of tendinosis often exists on other side
- Some tendon tears, especially those occurring spontaneously due to tendinosis, may present late
  - Partial gap in reparative hypoechoic granulation tissue may be seen in chronic tears
  - Mild hyperemia of granulation tissue is appreciated on color Doppler imaging
- Tendon subluxation may lead to restricted range of movement without tendon tear in, for example, ulnar subluxation in rheumatoid arthritis
- Ultrasound is accurate in detecting retear or defining cause of limitation of movement following repair
  - Suture material is often seen traversing gap
  - Limitation in movement of small tendons (finger tendons) may be due to tendon adhesions and not retear
- Tendon remains swollen and hyperemic long after tendon integrity and strength have returned
  - Especially true for larger tendons
  - Speed of rehabilitation best gauged clinically and not by serial ultrasound examination

MR Findings
- T1WI
  - Assess tendon enlargement + retraction
- T2WI
  - Disruption with discontinuity ± wavy retracted tendon
  - Enlarged tendon with intratendinous fluid or scar may be seen for up to 12 months post surgery

NON-ROTATOR CUFF TENDON TEARS

Imaging Recommendations
- Best imaging tool
  - Ultrasound diagnoses tendon tears with high accuracy and precision
- Protocol advice
  - Start by examining normal side to become familiar with normal anatomical appearances
  - For small tendons, examine first in transverse plane along length of tendon
    - Examine tendon slowly from distal to proximal, looking for any gap in tendon
  - Continually realign transducer to avoid anisotropy, which may mimic tears
  - Passive movement of affected tendon aids in identification of tendon ends
  - If bicipital groove or extensor carpi ulnaris groove is empty, check whether tendons have subluxed
  - For Achilles tendon examination, patient should be prone with foot dorsiflexed over end of bed
    - Examine also in full plantar flexion to determine tendon end apposition with plantar flexion
    - Measure distance of tear to musculotendinous junction and to calcaneal insertion
  - Mark retracted ends of tendons on skin to aid surgical exploration

DIFFERENTIAL DIAGNOSIS

Tenosynovitis
- Tendon sheath synovial proliferation; no tendon gap

Tendinosis With Peritendinitis
- Usually associated with small tendon tears
  - May be too small to resolve

PATHOLOGY

General Features
- Etiology
  - Younger patients tear large tendons during severe exertion
    - Typically, torn tendon either is normal or has mild tendinosis
  - Young to middle-aged patients tear large or medium-sized tendons during modest exertion
    - Typically, torn tendon has moderate or severe tendinosis
  - Elderly patients tear medium-sized or small tendons spontaneously or with minimal exertion
    - Typically, torn tendon has severe tendinosis
  - Other common etiological factors
    - Inflammatory arthropathy and particularly rheumatoid arthritis
      - Commonly affects extensor carpi ulnaris and extensor tendons of 4th and 5th fingers
      - Due to chronic friction from subluxed ulnar head ± chronic tenosynovitis
    - Malaligned fracture, such as distal radial fracture
      - Affects particularly flexor pollicis longus, tendon, and index finger flexor tendons
      - Chronic friction from malaligned fracture ± fixation plate
    - Chronic joint deformity, penetrating injury, and possibly repeated steroid injection

Gross Pathologic & Surgical Features
- Achilles tendon
  - Plantaris tendon usually remains intact
- Quadriceps tendon
  - Composed of 3 lamina: Superficial (from rectus femoris), intermediate (vastus lateralis and medialis), and deep (vastus intermedius)
  - Partial tears usually involve superficial &/or intermediate lamina

Microscopic Features
- Degeneration with decreased collagen cross-linking
  - Loss of viscoelasticity and increased stiffness

CLINICAL ISSUES

Presentation
- Most common signs/symptoms
  - Acute onset of pain ± swelling during exertion
  - Clinical assessment can be incorrect in up to 25%
- Clinical profile
  - Exertional activity in young/middle-aged subjects
  - Nonexertional activity in elderly subjects
  - Palpable tendon defect
  - In Achilles tendon exam, squeezing calf muscles normally causes plantar flexion (Thompson test)

Demographics
- Age
  - Most common after 30 years
- Gender
  - M:F = 5:1

Natural History & Prognosis
- Achilles tendon
  - Nonsurgical rate of rerupture: 21%
  - Surgical rate of rerupture: 2%

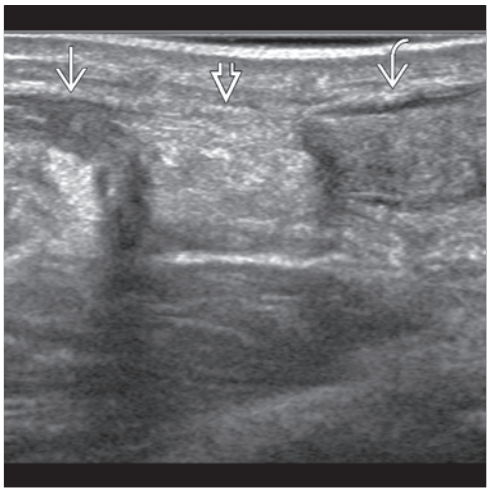
Treatment
- Achilles tendon tear
  - Cast immobilization
    - Above-knee cast with plantar flexion for 4 weeks followed by below-knee cast with decreased plantar flexion
    - Indicated for acute tears and when ultrasound shows good approximation of tendon ends with plantar flexion
  - Surgical repair is usually required
    - Either end-to-end anastomosis or tendon graft flap depending on length of tear
- Other tendons
  - Either surgical repair or no specific treatment

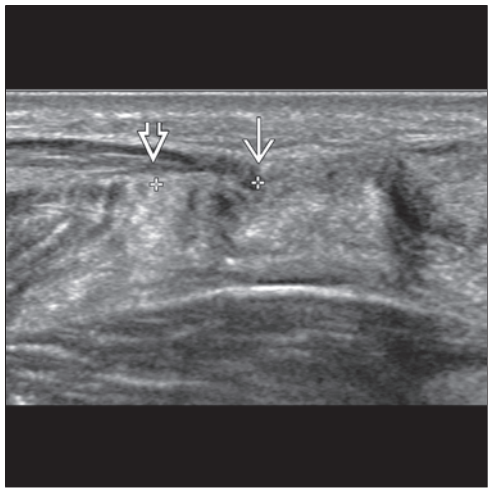
DIAGNOSTIC CHECKLIST

Image Interpretation Pearls
- Examine entire length of tendon, looking for fluid-filled gap, empty tendon sheath (small tendons), or focal depression of tendon surface

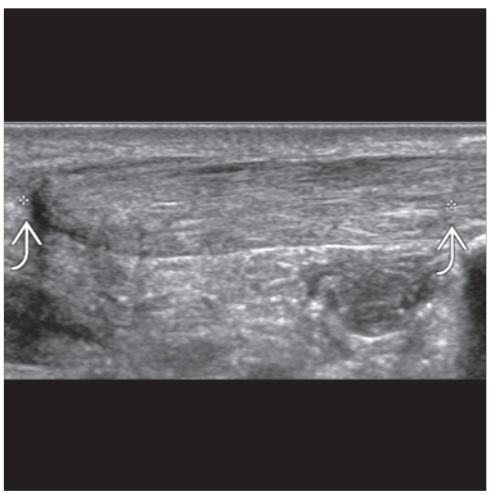
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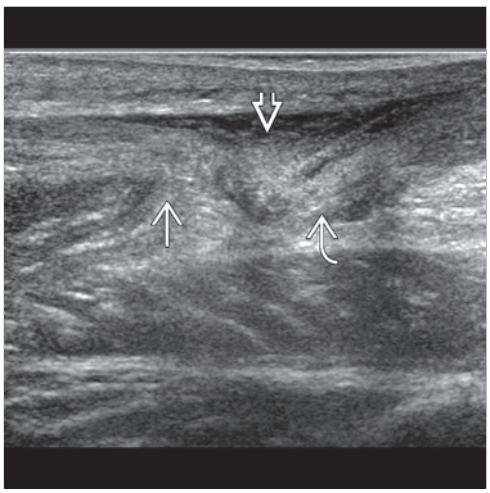


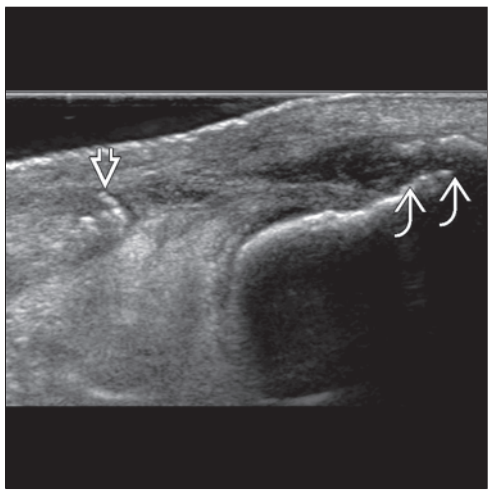
(Left) *Longitudinal ultrasound of an acute full thickness Achilles tendon tear shows a gap filled with echogenic edematous fat. The swollen proximal and distal ends of the tendon are shown. Most Achilles tendon tears occur just distal to the musculotendinous junction.* ***(Right)*** *Longitudinal ultrasound of the same torn Achilles tendon shows calipers measuring the distance of the end of the tear from the musculotendinous junction.*





(Left) *Longitudinal ultrasound of the same torn Achilles tendon shows calipers measuring the distance of the tear from the calcaneum. Note swelling of the Achilles tendon close to the tear.* ***(Right)*** *Clinical photo of the same patient shows the proximal and distal ends of the Achilles tendon as marked on the skin. Note the rounded skin depressions made with an upturned marker cap before the ultrasound gel was removed for ink marking.*

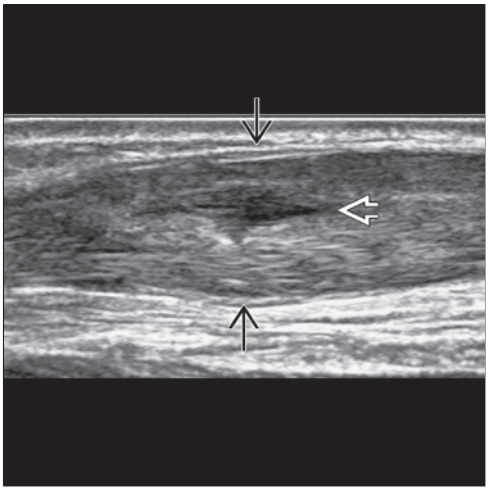


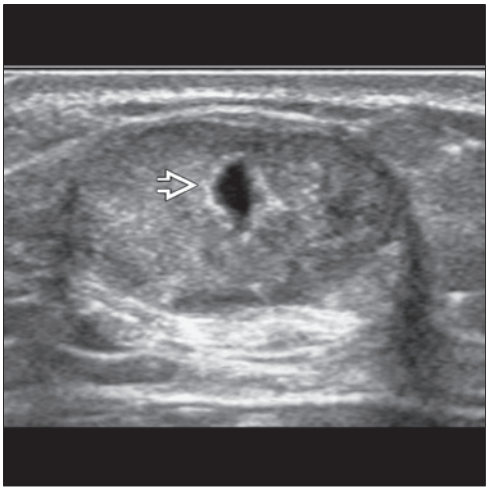


(Left) *Longitudinal ultrasound of an Achilles tendon shows a complete tear at the musculotendinous junction. The tear is filled with echogenic hematoma that partially obscures the proximal and distal tendon ends.* ***(Right)*** *Longitudinal ultrasound of an Achilles tendon shows complete tear (avulsion) from the calcaneal insertion. There is a small sliver of echogenic bone at the distal end of the retracted tendon. Most Achilles tendon tears from the calcaneum include a thin rim of bone.*

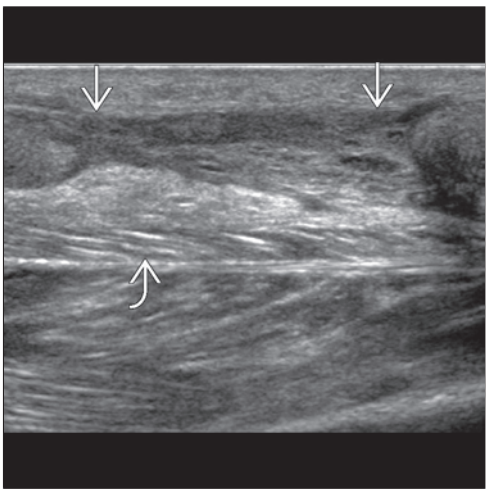
NON-ROTATOR CUFF TENDON TEARS

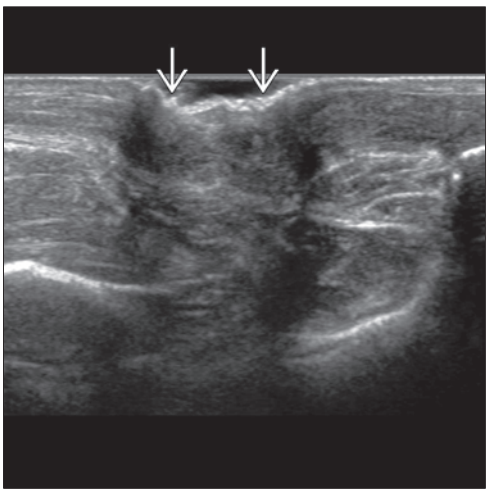
(Left) *Longitudinal ultrasound shows tendinosis and fusiform thickening of the midsegment of the Achilles tendon. A small longitudinal intrasubstance partial tear is located within the central portion of the tendon.* ***(Right)*** *Transverse ultrasound at the same location shows the intrasubstance tear of the Achilles tendon. Complete tears of the Achilles tendon are more common than partial tears.*



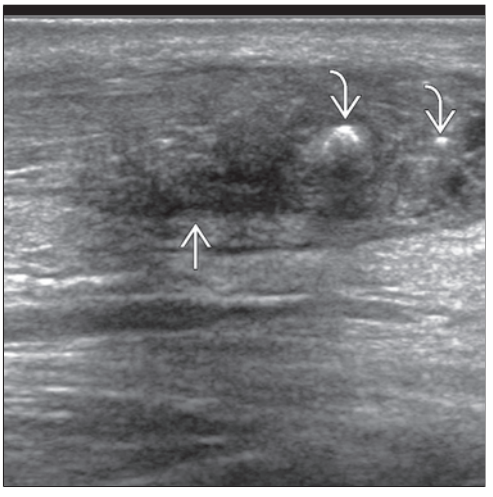


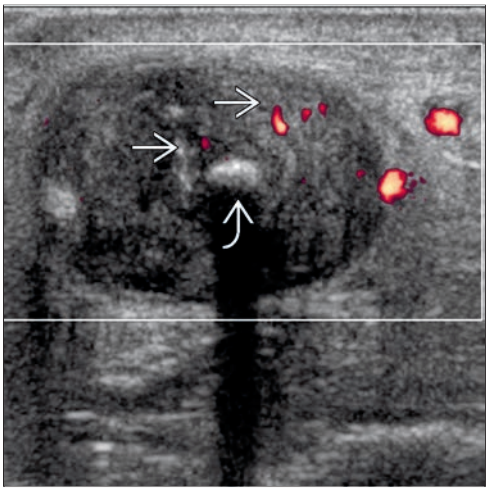
(Left) *Longitudinal ultrasound shows a complete chronic rupture of the Achilles tendon. There is a large retraction gap. The chronic tear is filled with echogenic fibrous material. The underlying soleus muscle is mildly atrophic.* ***(Right)*** *Extended field-of-view longitudinal ultrasound shows a chronic full thickness Achilles tendon tear that had been present for > 10 years. The tear is filled with fibrous-type tissue with overall redundancy and lengthening of the Achilles tendon.*



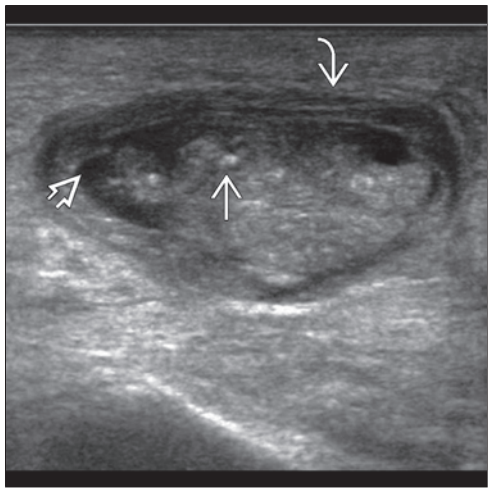


(Left) *Longitudinal ultrasound of an Achilles tendon in a patient with heel pain for 9 months and sudden complete tendon tear 2 months ago shows that the retracted proximal stump is severely swollen and heterogeneously hypoechoic with small flecks of calcifications suggestive of severe tendinosis.* ***(Right)*** *Transverse power Doppler ultrasound of the proximal stump of the Achilles tendon (same patient) shows moderate hyperemia and small flecks of calcifications within the tendon.*

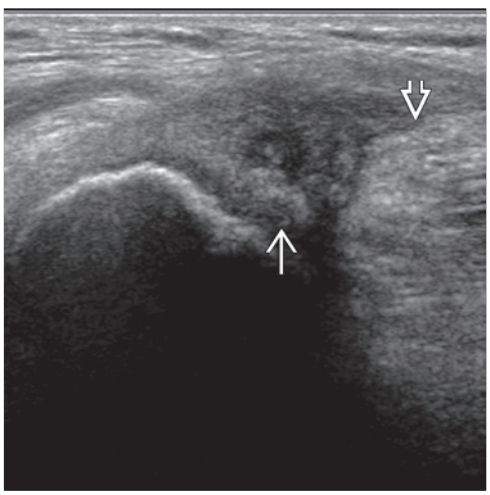


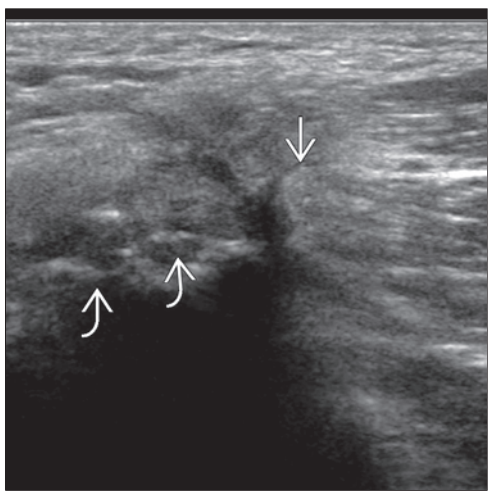






(Left) *Longitudinal ultrasound of the distal leg shows an acute complete Achilles tendon tear. The gap is filled with echogenic hematoma. The proximal end is swollen and irregular. Accurately determining the extent of preexisting tendinosis is difficult in this setting.* ***(Right)*** *Transverse ultrasound of the same tear shows small calcifications in a hematoma partially filling the tendon gap. Fluid is also present. The Achilles paratenon is moderately swollen.*





(Left) *Longitudinal ultrasound shows an acute tear of the adductor longus tendon close to the inferior pubic ramus attachment. Tendon fibers are retracted distally. The gap is partially filled with hematoma.* ***(Right)*** *Longitudinal ultrasound of the same patient close to the pubic tubercle shows a torn tendon with cortical irregularity of the insertional area. Tendon fibers are displaced distally.*

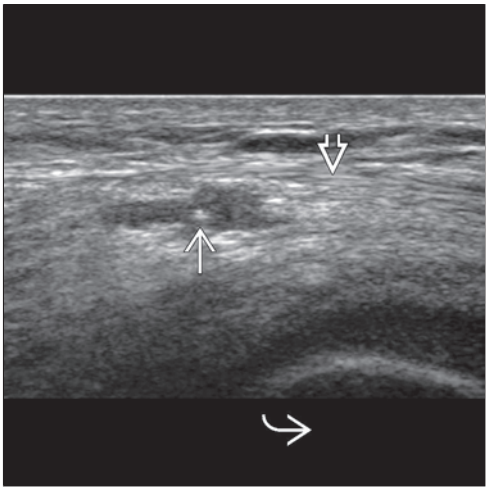


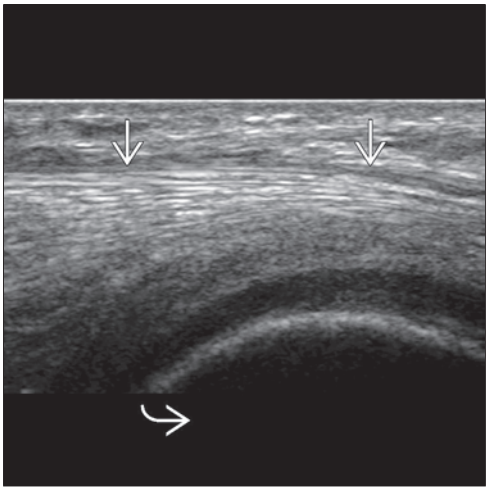


(Left) *Clinical photo shows a mass on the medial aspect of the distal thigh. The mass had been present for several years. It moved more distally and becomes more apparent with muscle contraction, and it almost disappeared with muscle relaxation.* ***(Right)*** *Longitudinal ultrasound of the thigh of the same patient shows incomplete rupture of the semimembranosus tendon from its proximal insertion and retraction to the midthigh region. There is a fibrotic mass at the site of the retracted torn tendon.*

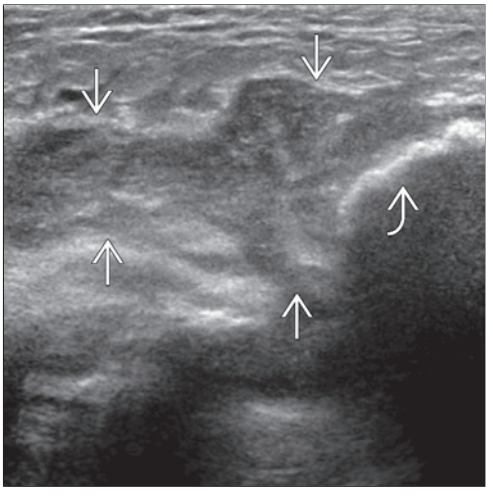
NON-ROTATOR CUFF TENDON TEARS

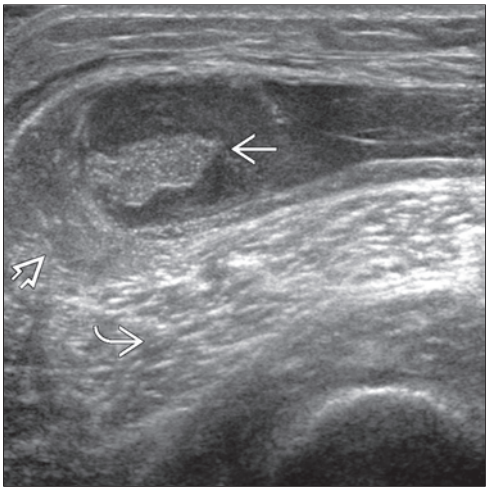
(Left) *Longitudinal ultrasound shows a chronic, deep-seated, intrasubstance semimembranous tendon tear. The superficial fibers are intact. The tear is sharp, irregular, and hypoechoic and likely to be filled with organizing hematoma and fibrotic tissue. Note the medial femoral condyle.* ***(Right)*** *Longitudinal ultrasound of the contralateral tendon (same patient) shows a normal fibrillar pattern of the semimembranous tendon coursing over the medial femoral condyle.*



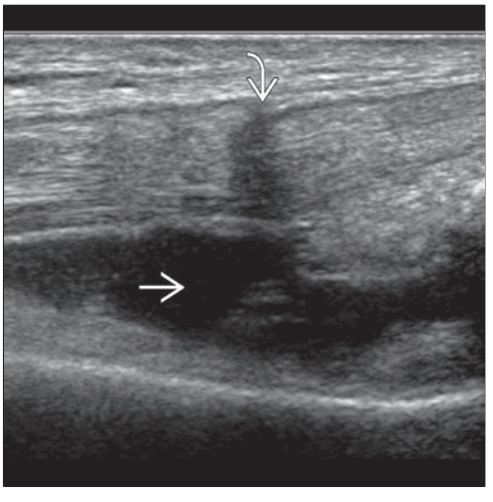


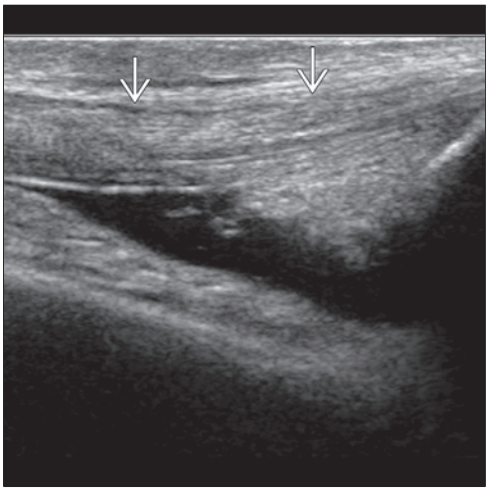
(Left) *Longitudinal ultrasound shows a complete quadriceps tendon tear at the superior pole of the patella. The proximal end of the tendon has retracted and is not visible on this image. The tendon gap is filled up with hemorrhagic fluid.* ***(Right)*** *Transverse ultrasound shows hemorrhage with blood clot within the tendon gap. Intact but edematous vastus medialis fibers are seen peripheral to the hematoma. Note the normal vastus intermedius muscle deep to the hemorrhagic area.*

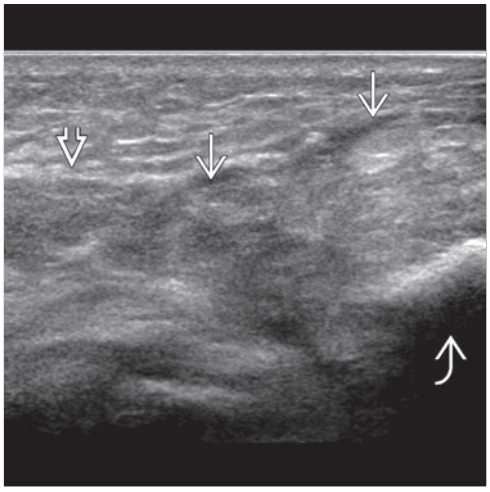


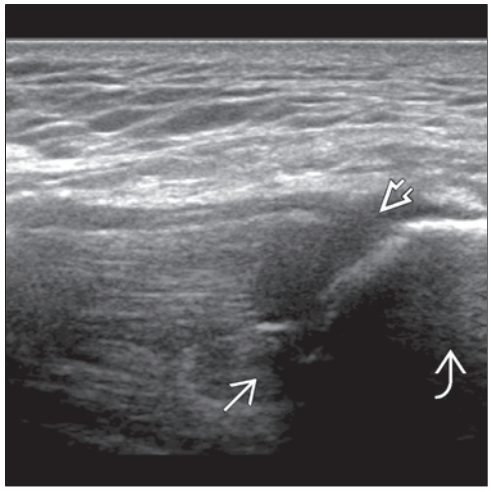


(Left) *Longitudinal ultrasound of a quadriceps tendon shows a localized tear of the lateral quadriceps tendon fibers with moderate distension of the suprapatellar pouch.* ***(Right)*** *Longitudinal ultrasound of the same quadriceps tendon shows intact medial fibers. The quadriceps tendon has 3 lamina: Superficial (rectus femoris), middle (vastus lateralis and vastus medialis), and deep (vastus intermedius). Partial tears may affect any part or all of these lamina.*

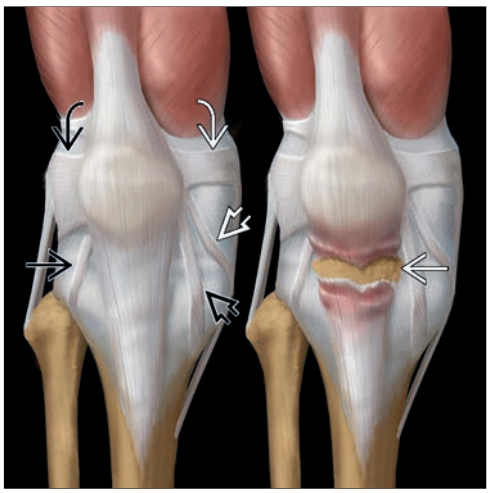


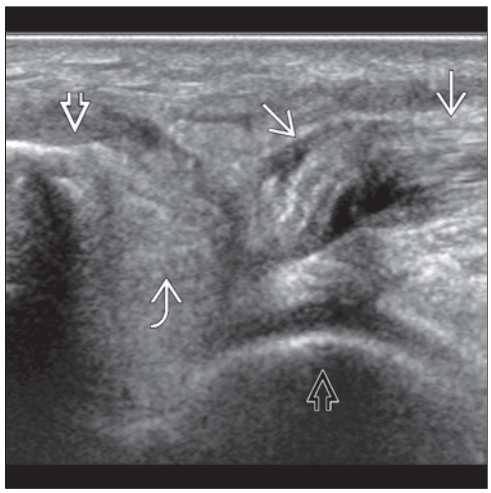




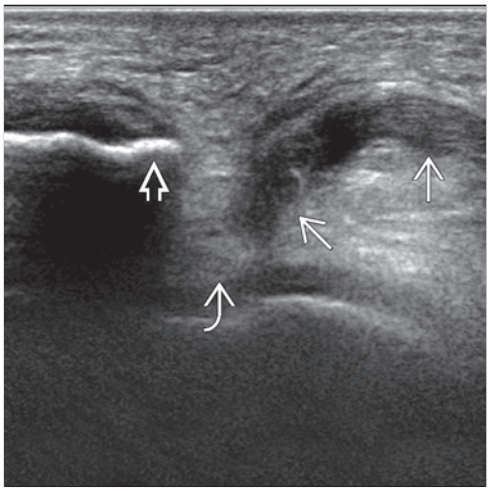


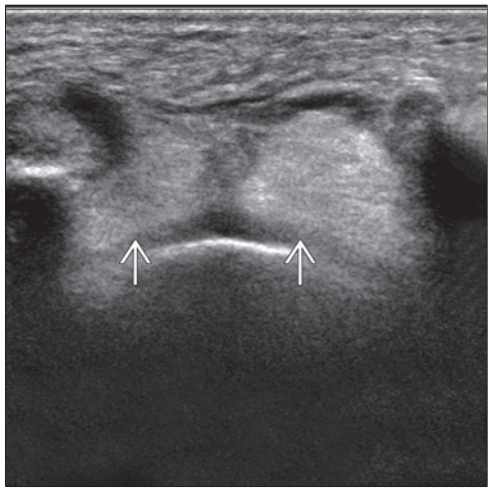
(Left) *Longitudinal ultrasound shows a complete rupture of the quadriceps tendon at the superior pole of the patella. The retracted tendon is not visible on this image. A hemorrhagic fluid tract fills the tendon gap.* ***(Right)*** *Longitudinal ultrasound shows a severe partial tear of the quadriceps tendon at the superior pole of the patella. About 80% of the depth of the tendon is torn. The deepest fibers of the quadriceps tendon are still intact.*





(Left) *Graphic shows a patellar tendon tear just distal to the patella, which is also stabilized by the medial and lateral patellofemoral ligaments. The less functionally relevant lateral and medial patellotibial ligaments as well as the patellomeniscal ligament are also shown.* ***(Right)*** *Longitudinal ultrasound shows an acute complete tear of the patellar tendon from the inferior pole of the patella. The gap is filled with echogenic blood. There is a resultant high-riding patella lying proximal to the femoral condyle.*



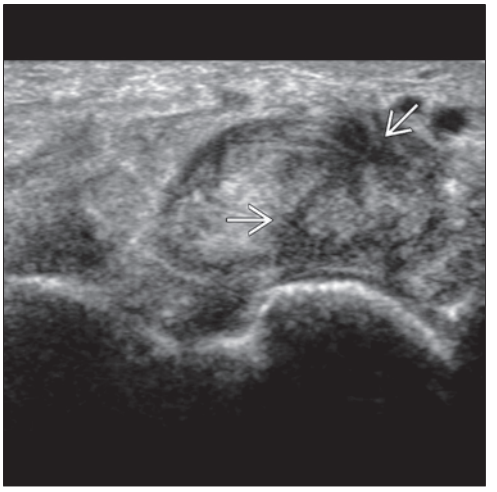


(Left) *Longitudinal ultrasound shows an acute complete tear of the patellar tendon from the inferior pole of the patella. The torn tendon is curved and displaced inferiorly. There is hemorrhage at the site of the tendon tear. Patellar tendon ruptures typically occur due to trauma in younger adults.* ***(Right)*** *Transverse ultrasound of the same patellar tendon tear allows better appreciation of the echogenic hematoma occupying the tendon tear gap.*

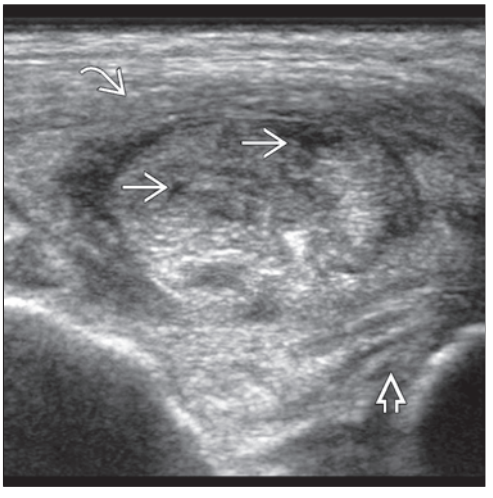
NON-ROTATOR CUFF TENDON TEARS

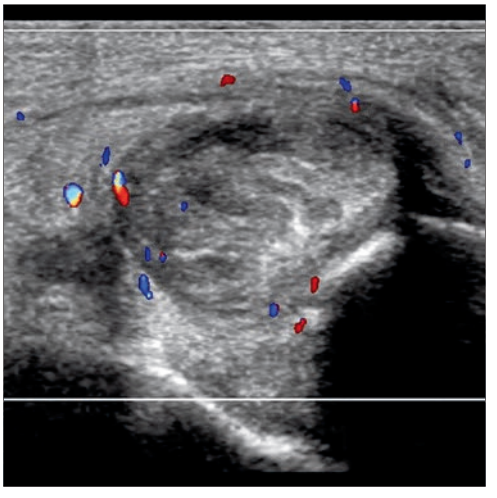
(Left) *Clinical photo shows quite severe pes planus with loss of the medial longitudinal arch leading to heel valgus deformity.* ***(Right)*** *Transverse ultrasound of the medial retromalleolar region shows severe posterior tibialis tendinosis with several irregular linear hypoechoic areas within the tendon substance consistent with longitudinal split tears. Longitudinal spit tears, which typically extend over 2-3 cm, are quite common in moderate to severe tendinosis of the tendons around the ankle.*



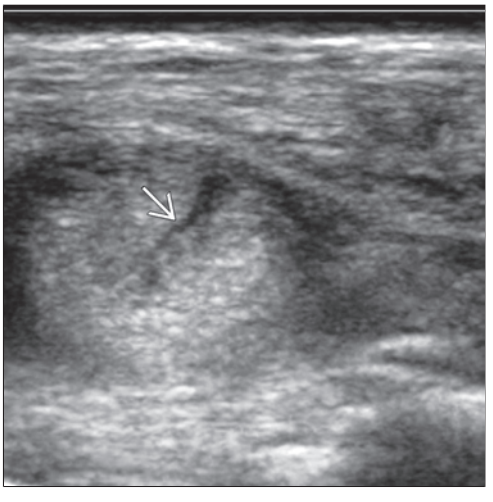


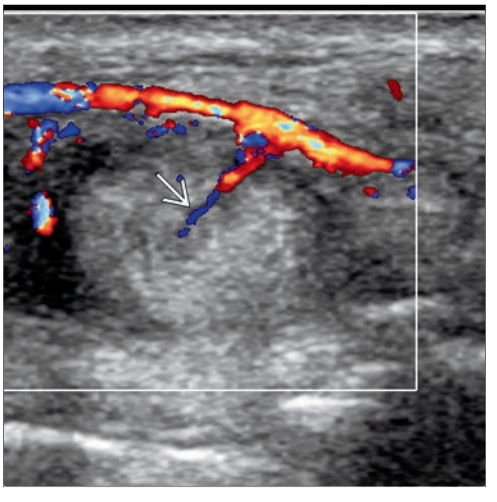
(Left) *Transverse ultrasound of the inframalleolar region shows several small linear hypoechoic split tears in the posterior tibialis tendon. Moderate background tendinosis is present. Linearity is the main feature that helps differentiate tendon tears from focal proteoglycan accumulation. Note the thickened flexor retinaculum. The deltoid ligament is present deep to the tendon.* ***(Right)*** *Transverse color Doppler ultrasound of the same tendon shows mild peritendinous and intrasubstance hyperemia.*

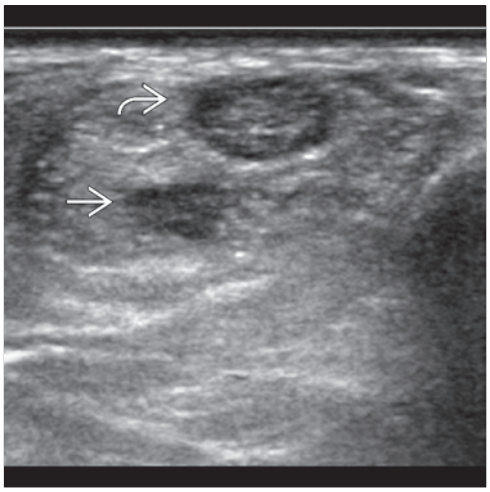


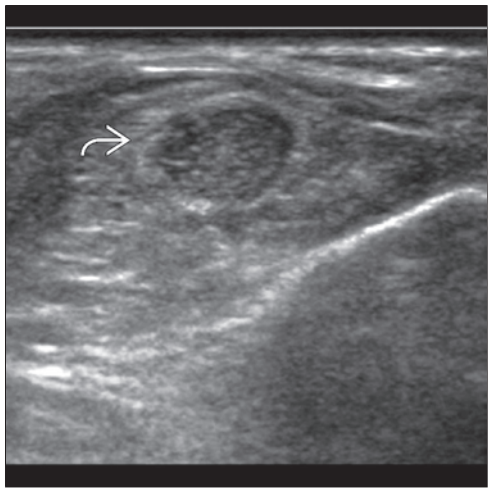


(Left) *Transverse ultrasound of the posterior tibialis tendon shows a linear discrete hypoechoic line extending from the surface to the center of the tendon, suspicious of a partial thickness tear. Always check any suspected partial tears with color Doppler ultrasound.* ***(Right)*** *Transverse color Doppler ultrasound of the corresponding region shows that the linear discrete hypoechoic line represents a vascular channel. This may be due to vascularized granulation tissue with a healing tear.*

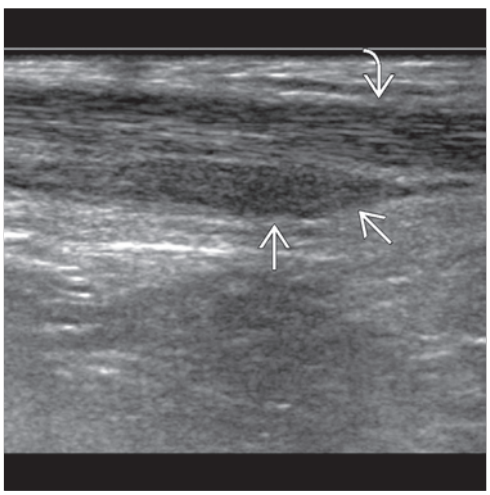


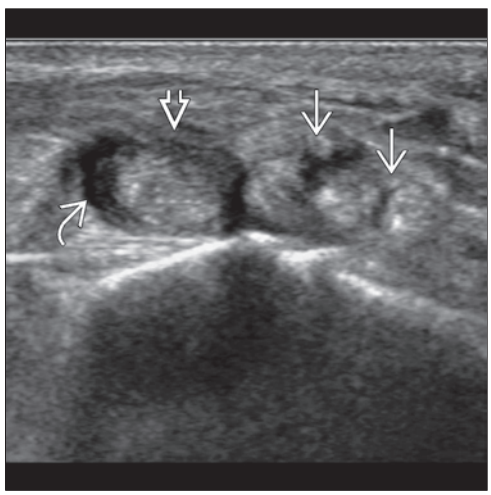




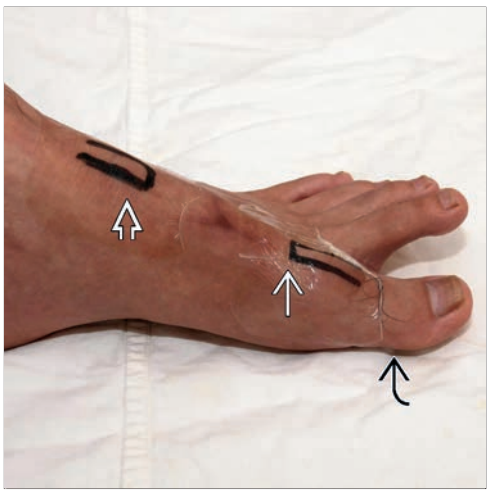


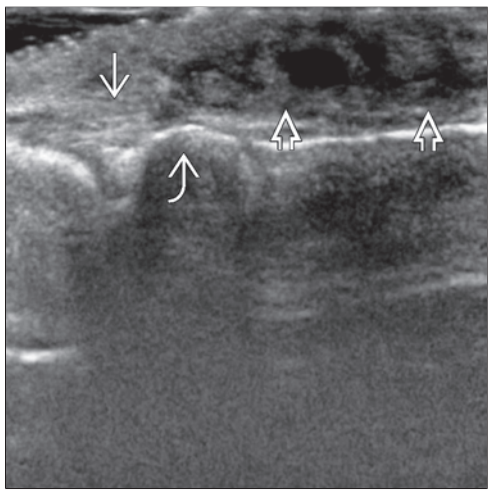
(Left) *Transverse ultrasound in the inframalleolar region shows normal peroneus longus and moderately attenuated peroneus brevis tendons.* ***(Right)*** *Transverse ultrasound at a site just proximal shows absence of the peroneus brevis tendon due to complete tear. The peroneus longus tendon is unchanged. Tears in the smaller tendons around the ankle and wrist are best appreciated first on transverse scanning along the tendon length.*





(Left) *Longitudinal ultrasound in the lateral retromalleolar area of the same complete tear of peroneus brevis tendon shows retraction of the swollen tendon end to the supramalleolar region. The peroneus longus tendon is intact.* ***(Right)*** *Transverse ultrasound of the lateral retromalleolar region shows complete longitudinal (split) tears of the peroneus longus tendon. There is mild peroneus brevis tendinosis with a small tendon sheath effusion but no tear.*

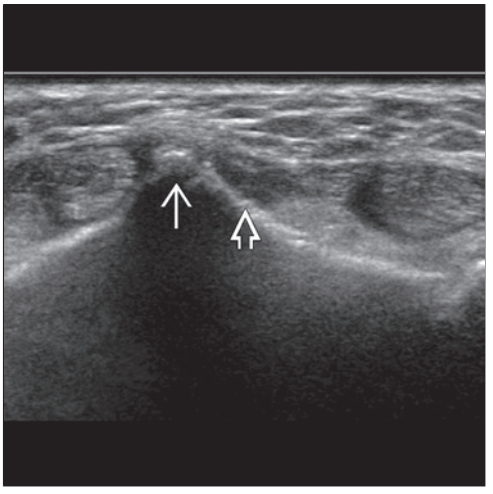


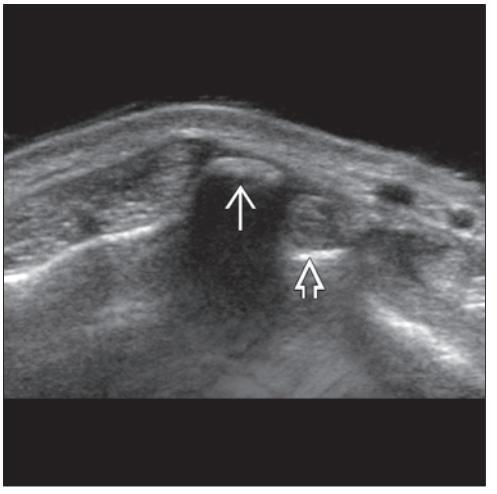


(Left) *Clinical photo from a patient with foot trauma and impaired big toe dorsiflexion shows the location of the distal and proximal stumps of the torn extensor hallucis longus drawn on the skin. Skin marking is helpful in subsequent surgical intervention.* ***(Right)*** *Longitudinal ultrasound shows a complete tear of the extensor hallucis longus with proximal retraction to the navicular bone level. There is a hematoma filling the tendon gap overlying the 1st metatarsal shaft.*

NON-ROTATOR CUFF TENDON TEARS

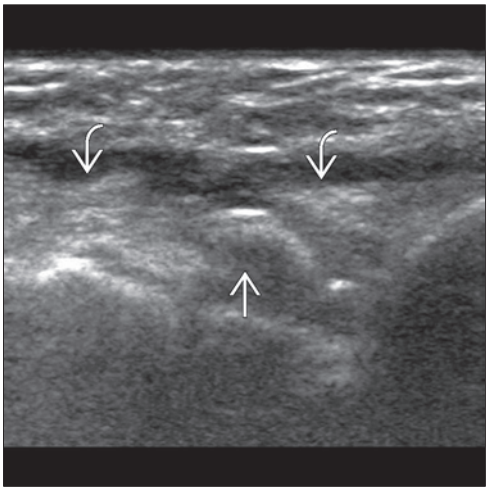
(Left) *Transverse ultrasound in a patient with limited thumb movement shows absence of the extensor pollicis longus tendon at the distal radius level. The tendon is normally located just ulnar to the Lister tubercle. **(Right)** Transverse ultrasound of the contralateral normal extensor pollicis longus shows the tendon readily identified adjacent to the Lister tubercle. Deep to the extensor retinaculum (3rd compartment) is the most common site of extensor pollicis longus tendon rupture.*



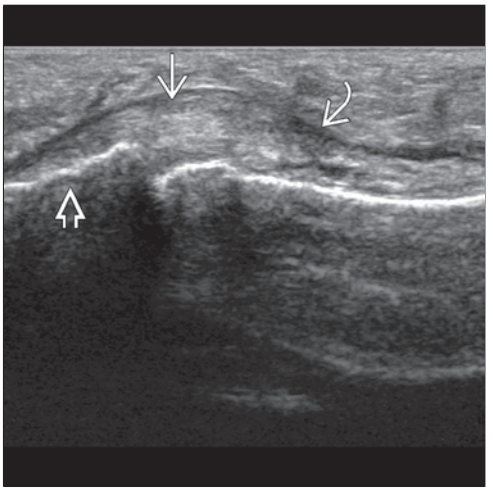


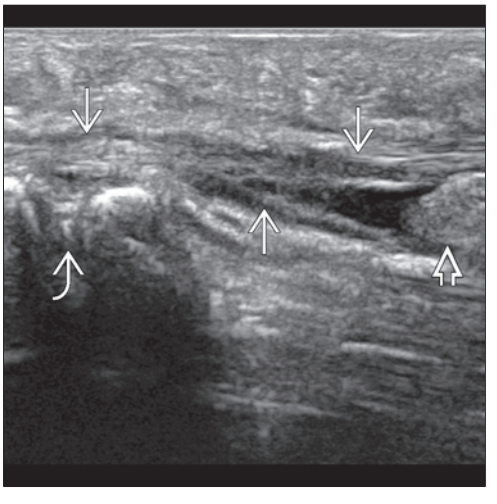
(Left) *Clinical photo of the same patient shows the sites of the retracted proximal and distal ends of the torn extensor pollicis longus tendon. **(Right)** Longitudinal ultrasound shows an empty tendon sheath following complete rupture of the extensor indicis tendon. The tendon ends are not shown. There is an abnormal ossicle on the dorsum of the scapholunate junction, which most likely precipitated the tendon tear. Subsequent CT confirmed this accessory ossicle of uncertain etiology.*

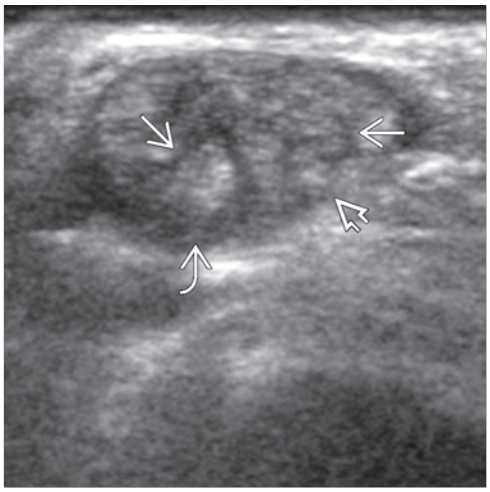


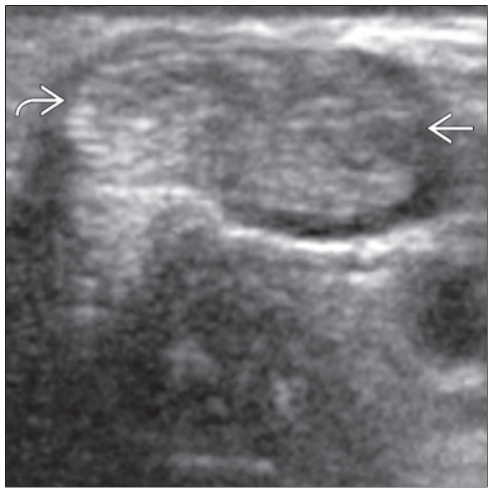


(Left) *Longitudinal ultrasound shows a complete tear of the flexor pollicis longus tendon following direct trauma to the thumb. A swollen distal tendon stump is inserted into the base of the distal phalanx. **(Right)** Longitudinal ultrasound of the same tear shows a retracted proximal stump. The collapsed tendon sheath is swollen and contains fluid. The metacarpophalangeal joint is normal. Most flexor pollicis longus tears occur more proximally following volar plating of distal radial fractures.*

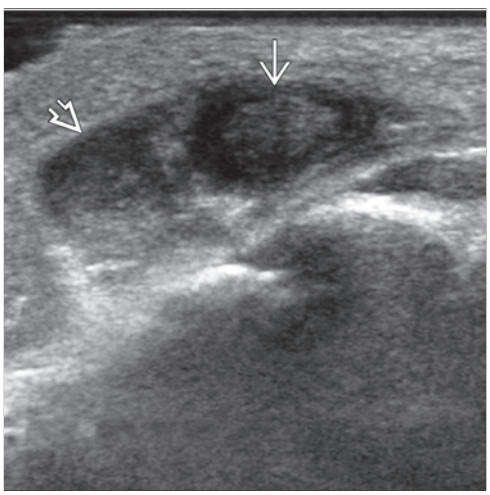


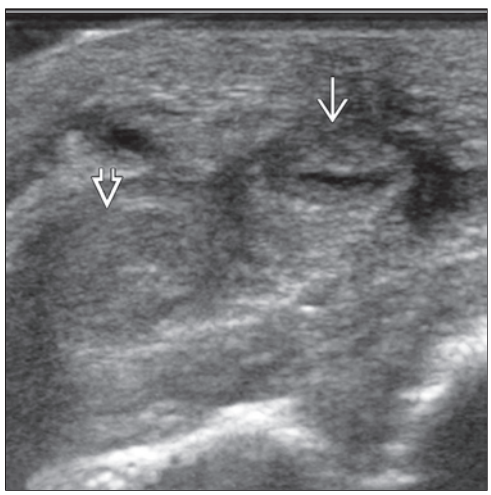




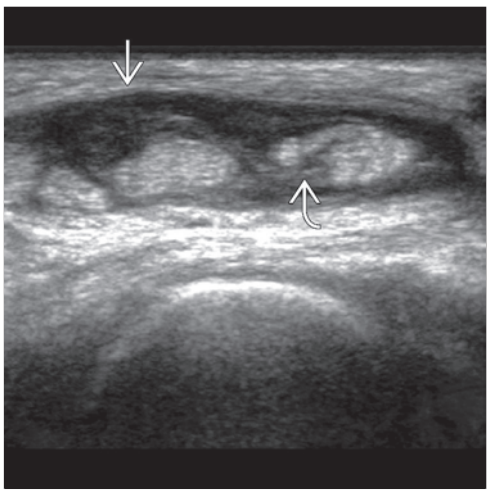


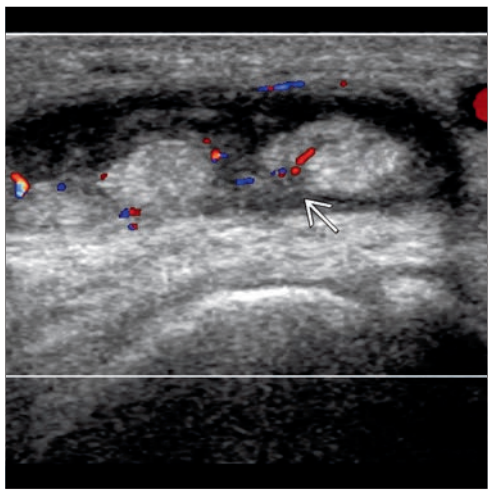
(Left) *Transverse ultrasound of the 1st extensor compartment of the symptomatic wrist shows mild tendinosis of both the abductor pollicis longus and the extensor pollicis brevis tendons. Small split tears are present in these tendons.* ***(Right)*** *Transverse ultrasound of the contralateral asymptomatic wrist shows moderate tendinosis of the abductor pollicis longus and extensor pollicis brevis tendons with no tendon tear.*





(Left) *Transverse ultrasound of the dorsum of the hand shows severe tendinosis of the extensor digitorum tendons to the index and middle fingers.* ***(Right)*** *Transverse ultrasound of the dorsum of the hand obtained just proximal to the previous image shows an empty, swollen, partially collapsed tendon sheath of the extensor indicis tendon, consistent with a complete tear. The intact tendinopathic middle finger extensor tendon is also shown.*





(Left) *Transverse ultrasound of the dorsum of the hand of a 28-year-old man following direct trauma 1 week earlier shows a moderately severe extensor tenosynovitis with a small longitudinal split in the extensor indicis tendon.* ***(Right)*** *Transverse color Doppler ultrasound shows the previously noted tendon tear to be vascularized. This most likely represents reparative vascularization. Vascularized granulation tissue within tears can look similar to channel-like vascular ingrowth.*

TENOSYNOVITIS

Key Facts

Imaging

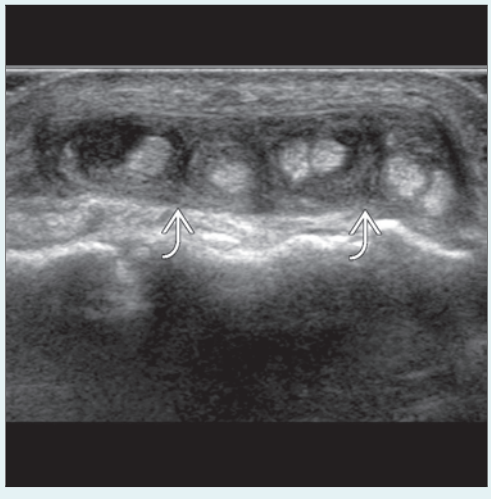
- Occurs only in tendons encased by synovium
- Distension of tenosynovium (tendon sheath) due to fluid or synovitis with variable tendon swelling
- **Acute exudative tenosynovitis**
  - Usually due to acute infection
  - Fluid accumulation within sheath with little or no synovial proliferation
  - Fluid usually has speckled appearance due to aggregates of purulent debris
- **Acute nonexudative tenosynovitis**
  - Synovial proliferation within sheath predominates over fluid accumulation
- **Chronic tenosynovitis (active)**
  - Similar to acute nonexudative tenosynovitis except that hyperemia is > within sheath
- **Chronic tenosynovitis (inactive)**
  - Clear fluid accumulation within mildly thickened sheath
  - Hyperemia mostly around, rather than within, tendon sheath
- **Stenosing tenosynovitis**
  - Hypertrophy of retinaculum or pulley component of tendon osseofibrous tunnel
  - Restricts tendon movement (trigger finger and de Quervain disease)
  - Thickening (1-1.5 mm) of pulley or retinaculum (normal thickness: ≤ 0.5 mm)

Diagnostic Checklist

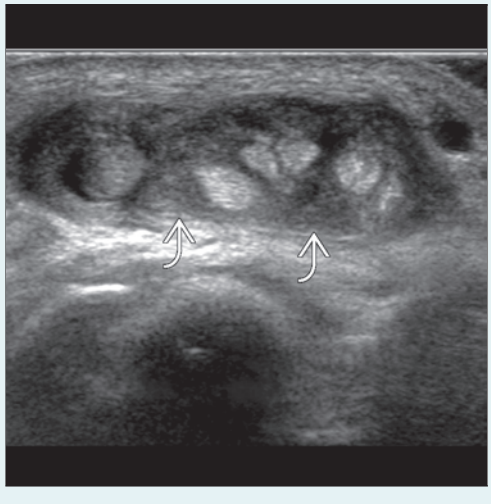
- Tenosynovitis: Disease of tendon sheath with minimal tendon involvement
- Tendinosis: Disease of tendon with variable degree of peritendinitis
- Use color Doppler to distinguish synovial inflammation from synovial effusion

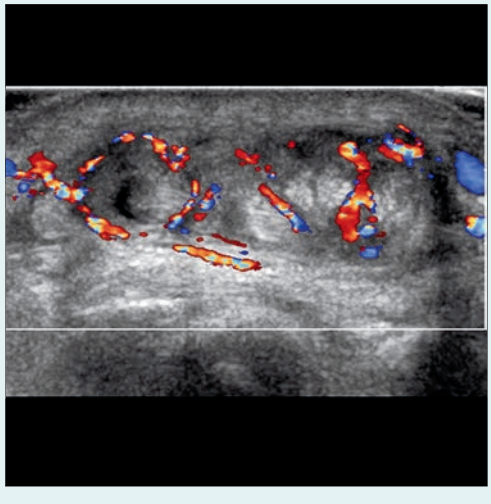
(Left) *Clinical photograph shows severe swelling dorsum of the wrist in a patient with a 2-week history of increasing wrist pain.* ***(Right)*** *Transverse ultrasound at the metacarpal level shows a severely thickened tendon sheath* ⇄ *around the extensor digitorum communis tendon. Synovial proliferation is present. The extensor digitorum tendons are only mildly swollen.*





(Left) *Transverse ultrasound of the same patient's wrist at the level of the proximal carpal row shows even more severe distension of the extensor digitorum communis tendon sheath with thickened proliferative synovium* ⇄. ***(Right)*** *Transverse color Doppler ultrasound of the extensor digitorum communis tendon sheath (same patient) shows severe hyperemia of the thickened synovium, consistent with active chronic tenosynovitis.*





TENOSYNOVITIS

TERMINOLOGY

Synonyms
- Tendinitis or tendonitis are arbitrary terms best avoided

IMAGING

General Features
- Best diagnostic clue
  - Inflammation of tendon sheath (tenosynovium)
  - Thickening of synovial tendon sheath (synovial proliferation) ± tendon sheath exudate or fluid
- Location
  - Can occur only in tendons encased by synovial sheath
    - For example, tenosynovitis cannot occur on extensor aspect of fingers due to lack of a tendon sheath in this area
  - Wrist extensors > wrist flexors > finger flexors > ankle tendons
- Morphology
  - Distension of tendon sheath with mild tendon swelling
  - Variable tendon sheath distension and content, depending on cause, severity, duration

Radiographic Findings
- Radiography
  - Signs of underlying cause
    - Calcifications in gouty tophi or calcium pyrophosphate dihydrate deposition (CPPD)
    - Erosive or septic arthropathy
    - Radiopaque foreign body

MR Findings
- T1WI
  - Hypo- to isointense fluid in distended synovial sheath
- T2WI
  - Intermediate to hyperintense fluid within distended synovial sheath
- T1WI C+ FS
  - Contrast enhancement helps differentiate synovial proliferation from tendon sheath fluid

Ultrasonographic Findings
- Depends on capacity of tendon sheath to distend
- **Acute exudative tenosynovitis**
  - Due to infection or gout
    - Fluid accumulation within tendon sheath with little or no synovial proliferation
    - Fluid usually has speckled appearance due to aggregates of purulent debris
      - Echogenic speckles from gout tend to be larger than those due to inflammatory aggregates in infected synovial fluid though overlap exits
    - Hyperemia around though not within tendon sheath
    - Infection may spread from tendon sheath into peritendinous tissues
    - ± foreign body within tendon sheath
- **Acute proliferative tenosynovitis**
  - Due to inflammation or infection
    - Distension of tendon sheath with minimal or no tendon swelling
    - Synovial proliferation within sheath predominates over fluid accumulation
    - Acute hyperemia predominantly around (rather than within) tendon sheath
  - Mild secondary tenosynovial swelling can occur in presence of severe cellulitis or edema
- **Chronic tenosynovitis (active)**
  - Due to inflammation or infection
  - Markedly thickened tendon sheath due to synovial proliferation rather than fluid
    - Synovial proliferation particularly prevalent in tuberculous tenosynovitis
  - Established hyperemia both within and around tendon sheath
- **Chronic tenosynovitis (inactive)**
  - Either synovial proliferation or clear fluid accumulation within mildly thickened sheath
    - Multiple small rice bodies (fibrinous nodules) may develop in chronic infection (e.g., TB) or inflammation (e.g., rheumatoid arthritis)
    - Adhesions can lead to entrapped tenosynovial fluid with marked distension
  - Little or no hyperemia either around or within tendon sheath
- **Stenosing tenosynovitis**
  - Describes tendon disorders associated with hypertrophy of fibrous component of tendon osseofibrous tunnel
  - Contentious "tenosynovitis" terminology as this entity is more related to tendinosis than to tenosynovitis
  - Hypertrophy of flexor pulley (trigger finger) or 1st extensor retinaculum (de Quervain disease)
    - For trigger finger, A1 pulley is thickened more frequently than A2 pulley and any finger may be affected
  - Thickening (1-1.5 mm) of pulley or retinaculum
    - Normal thickness of pulley/retinaculum ≤ 0.5 mm
  - Tendon thickening
  - Peritendinous and intratendinous hyperemia
  - Occasional tendon sheath effusion
  - Restriction of tendon movement on dynamic imaging

Imaging Recommendations
- Best imaging tool
  - Ultrasound: Accurate at revealing presence and extent of tenosynovitis
    - Facilitates fine-needle aspiration (for culture, crystals) or biopsy to determine cause
    - US-guided steroid injection treatment
- Protocol advice
  - Examine full length of tendon or group of tendons in transverse plane
  - Use minimal transducer pressure to avoid effacing tendon sheath effusion or vascularity
  - Always include evaluation with color Doppler
    - Helps distinguish synovial proliferation from synovial fluid
  - Examine nearby joints for synovitis or effusion
  - Look for fluid leakage outside tendon sheath
  - Compare with contralateral normal side

TENOSYNOVITIS

- In stenosing tenosynovitis, measure thickness of retinaculum or pulley
  - Measure retinacular or pulley thickness at 10-o'clock or 2-o'clock positions
  - Perform dynamic assessment of tendon movement

DIFFERENTIAL DIAGNOSIS

Tendinosis

- Disease of tendon with variable degree of peritendinitis
- Tendon swelling, disruption of fibrillar echotexture, and intratendinous hyperemia predominate
  - Tendon sheath swelling is less than in tenosynovitis
- Intratendinous neovascularization is not a usual feature of tenosynovitis
- Distinction between tenosynovitis and tendinosis is not always clear-cut; mixed patterns may exist

PATHOLOGY

General Features

- Etiology
  - Overuse, infection (acute or chronic), systemic inflammatory arthropathy, crystal deposition
  - Often no specific cause is found
- Relevant anatomy: Wrist flexor tendons
  - Flexor tendon sheaths of thumb and little finger communicate via radial and ulnar bursae, respectively, on volar aspect of wrist
  - In 50% of cases, radial and ulnar bursae communicate via intermediate bursa
- Relevant anatomy: Wrist extensor tendons
  - 6 discrete extensor tendon sheaths that do not communicate
  - Extensor tendon expansions on dorsum of fingers do not have tendon sheaths
- Relevant anatomy: Stenosing tenosynovitis
  - 1st extensor compartment, radial side of anatomical snuff box
  - Larger abductor pollicis longus and smaller extensor pollicis brevis
  - Septum separates both tendons in 25% of cases
  - Superficial branch of radial nerve overlies 1st extensor compartment

Gross Pathologic & Surgical Features

- Inflammation of tendon sheath
- Thickening of tendon retinaculum or pulley

Microscopic Features

- Inflammatory cells infiltrate tenosynovium
- Retinaculum and pulley are histologically identical with 3-layer structure
  - Superficial layer: Loose connective tissue (nutritional layer)
  - Intermediate layer: Fibrous tissue (mechanical layer)
  - Deep layer: Flattened fibroblasts, cells that secrete hyaluronic acid, ± areas of chondroid metaplasia (gliding layer)

CLINICAL ISSUES

Presentation

- Most common signs/symptoms
  - Pain, swelling, and tenderness of affected tendons
  - Limitation of movement
- Other signs/symptoms
  - Crepitus, tendon triggering
  - Surrounding cellulitis

Demographics

- Age
  - Most common in middle-aged to elderly people
- Gender
  - Inflammatory tenosynovitis, de Quervain tenosynovitis, and repetitive strain injury have female predominance
- Epidemiology
  - Inflammatory tenosynovitis is common in athletes and repetitive strain injury patients
  - Infective tenosynovitis is more common in immunosuppressed patients and patients prone to penetrating injury
  - Stenosing tenosynovitis is associated with estrogen metabolism
    - Hormone receptors present in intermediate layer of extensor retinaculum
    - Associated with aromatase inhibitors and tamoxifen ingestion
    - Increased post partum (baby wrist) and in diabetes

Natural History & Prognosis

- Majority (80%) improve with conservative treatment
  - If infective, may need surgical drainage

Treatment

- Noninfective tenosynovitis and chronic infective tenosynovitis
  - Rest, splinting, physiotherapy
    - Anti-inflammatory medication ± ultrasound-guided steroid injection
    - ± appropriate antibiotics
    - Synovectomy for failed conservative treatment
- Acute exudative tenosynovitis
  - Surgical drainage, elevation, antibiotics
- Stenosing tenosynovitis
  - Ultrasound-guided steroid injection into tendon sheath near pulley or retinaculum
    - High success rate, especially for trigger finger

DIAGNOSTIC CHECKLIST

Consider

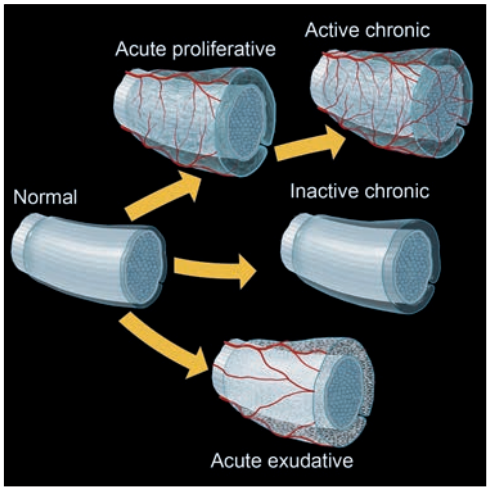
- Tendinosis rather than tenosynovitis if tendon is predominantly swollen with intratendinous hyperemia
- Secondary tenosynovial swelling if there is severe surrounding cellulitis or edema

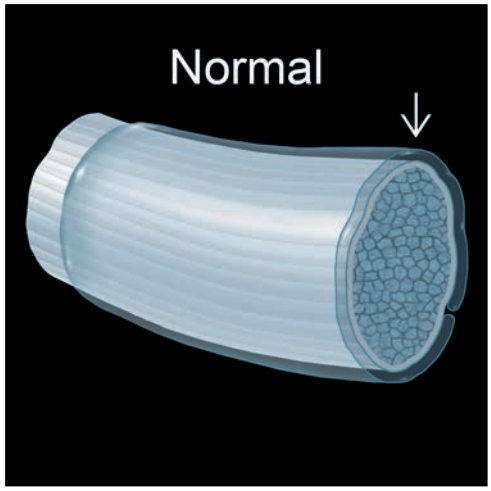
Image Interpretation Pearls

- Use color Doppler to distinguish synovial inflammation from synovial effusion

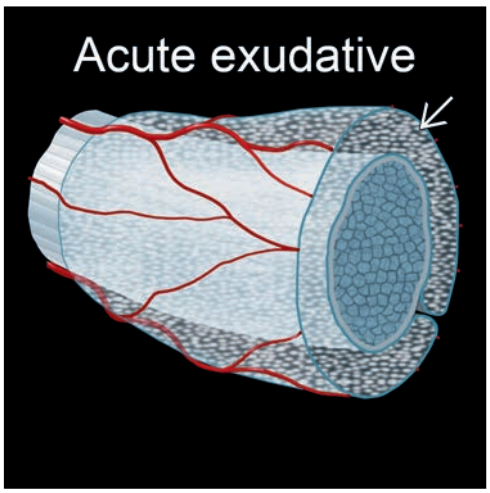
SELECTED REFERENCES

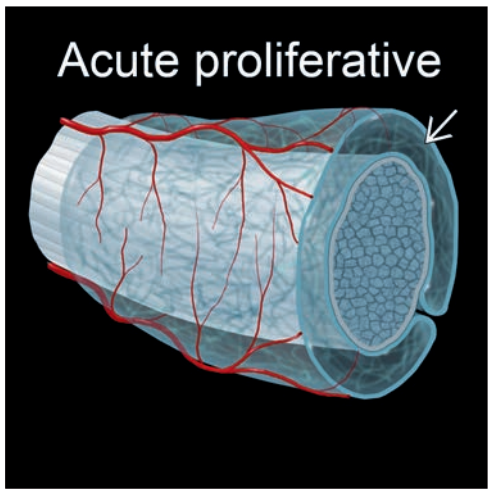
1. Vuillemin V et al: Stenosing tenosynovitis. J Ultrasound. 15(1):20-8, 2012
2. Chau CL et al: Musculoskeletal infections: ultrasound appearances. Clin Radiol. 60(2):149-59, 2005



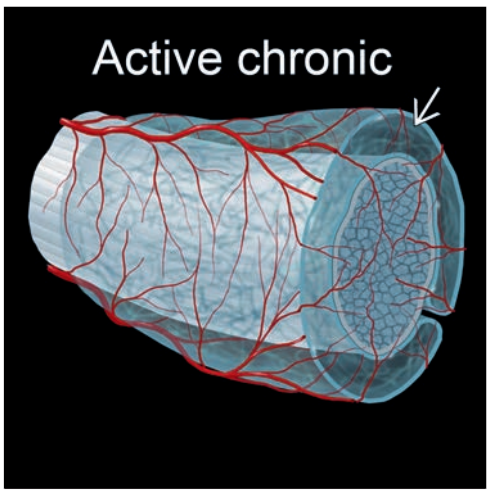


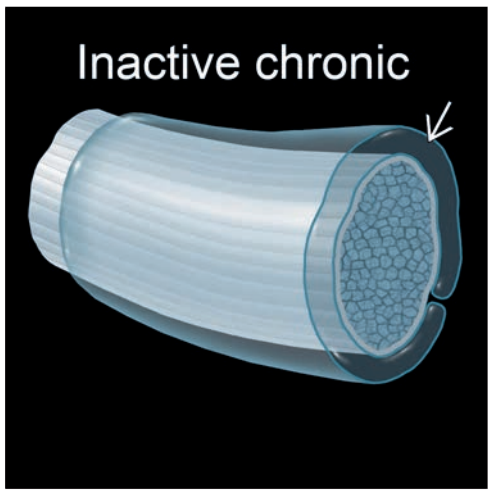
(Left) *Graphic shows different types of tenosynovitis. Tenosynovitis is a disease of the tendon sheath. Unlike tendinosis which can affect any tendon, tenosynovitis can only affect those tendons with a tendon sheath.* ***(Right)*** *Graphic shows normal tendon and sheath* ➔ *for comparative purposes. Most, but not all the tendons, of the wrist/hand and ankle/ foot have a tendon sheath. The long head of biceps has a tendon sheath. The patellar and Achilles tendons have a paratenon. All other tendons without a tendon sheath cannot be affected by tenosynovitis.*





(Left) *Graphic shows acute exudative tenosynovitis* ➔*, usually secondary to bacterial infection/penetrating trauma and is rapidly progressive. Purulent exudate can be aspirated. Hyperemia occurs around, rather than within, the tendon sheath.* ***(Right)*** *Graphic shows acute proliferative tenosynovitis. This is a proliferative, rather than an exudative, tenosynovitis usually due to repetitive trauma or a systemic inflammatory disorder. Tendon swelling occurs due to synovial proliferation* ➔ *with a mild serous exudate. Hyperemia is limited to the tendon sheath surface.*

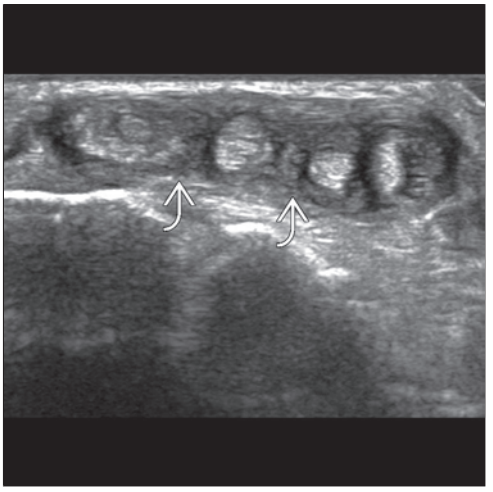


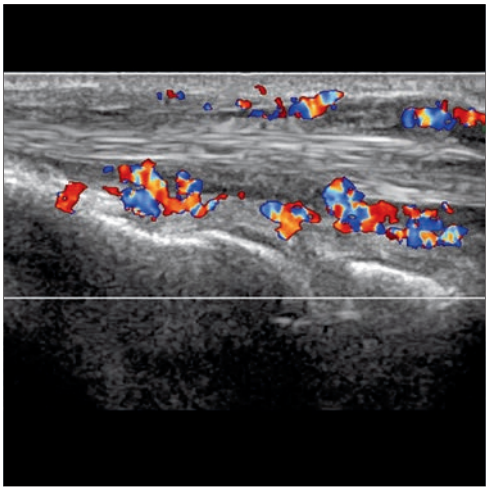


(Left) *Graphic shows active chronic tenosynovitis. Mature hyperemic synovial proliferation* ➔ *fills the distended tendon sheath. Hyperemia may extend into the tendon, which may be slightly enlarged due to edema. Otherwise, the tendon remains normal in appearance.* ***(Right)*** *Graphic shows inactive chronic tenosynovitis. The tendon sheath is distended with serous fluid* ➔*. This distension may be severe and localized due to tendon sheath adhesions. Little or no hyperemia is present.*

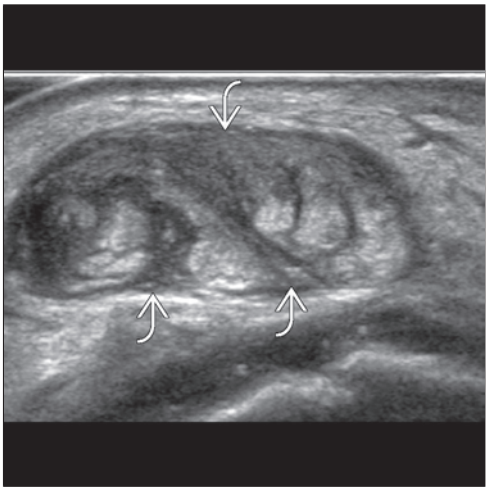
TENOSYNOVITIS

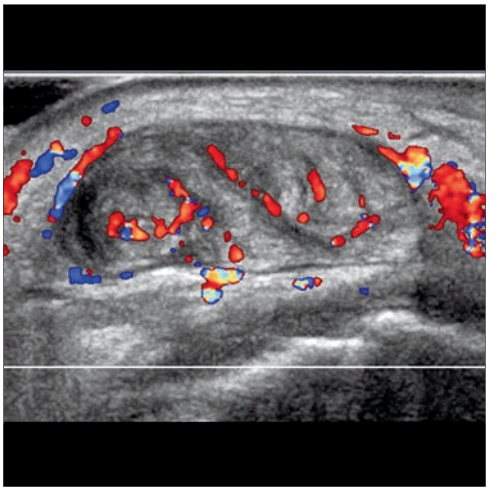
(Left) *Transverse ultrasound of the dorsal wrist in a patient with a 2-month history of wrist swelling shows moderately severe synovial thickening* ➔ *with no visible tendon sheath effusion, suggestive of chronic tenosynovitis. Note mild swelling of the extensor digitorum tendons.* ***(Right)*** *Longitudinal color Doppler ultrasound of the ring finger extensor tendon (same patient) shows synovial thickening extending along the dorsum of the hand with severe hyperemia, consistent with active chronic tenosynovitis.*





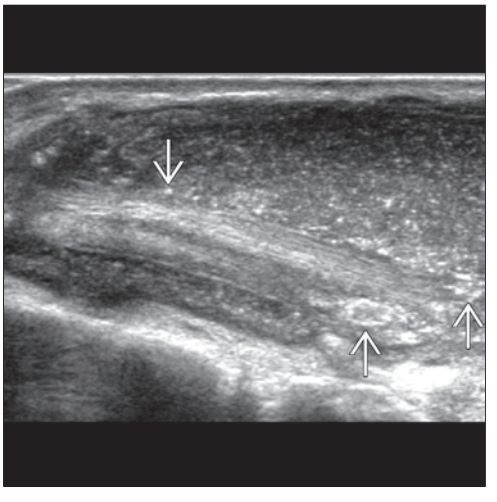
(Left) *Transverse ultrasound of the extensor digitorum communis in a patient with a history of gout and progressive wrist swelling for 3 months shows severe synovial thickening* ➔ *surrounding the mildly swollen tendons, suggestive of chronic tenosynovitis.* ***(Right)*** *Transverse color Doppler ultrasound at the same level shows severe peritendinous hyperemia, suggestive of active chronic tenosynovitis.*

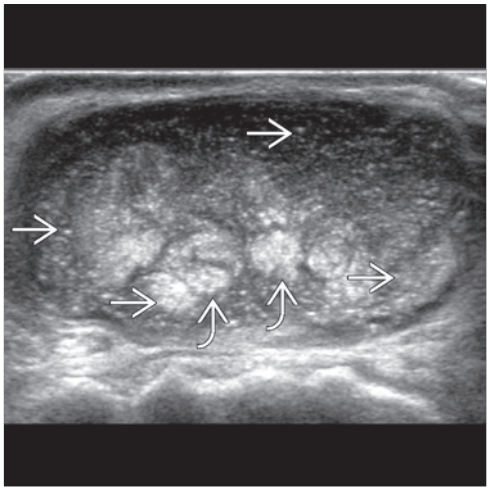


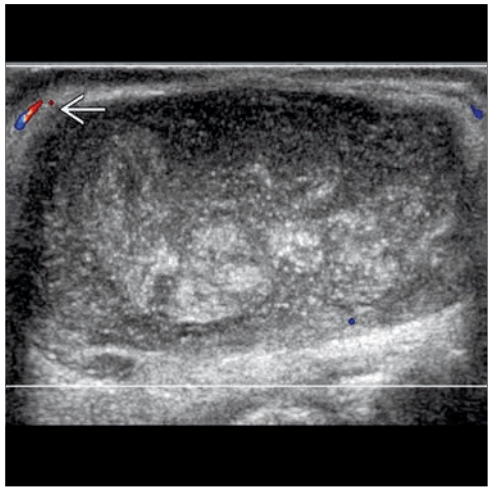


(Left) *Clinical photograph of patient with a history of gout shows marked swelling on the dorsum of the wrist with erythema.* ***(Right)*** *Longitudinal ultrasound of the same wrist shows marked distension of the common extensor digitorum tendon sheath. Small echogenic speckles* ➔ *within the thickened tenosynovium are consistent with crystal aggregates. These features are compatible with a gouty tenosynovitis.*

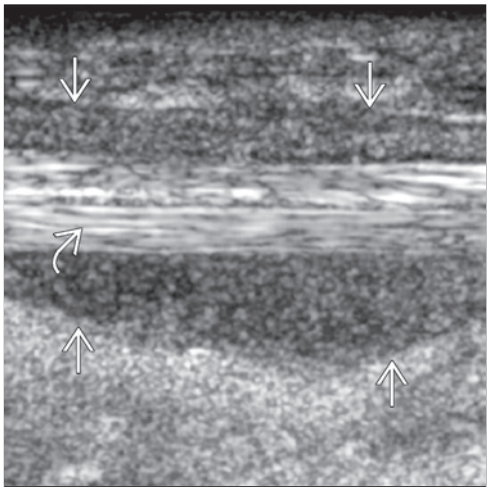


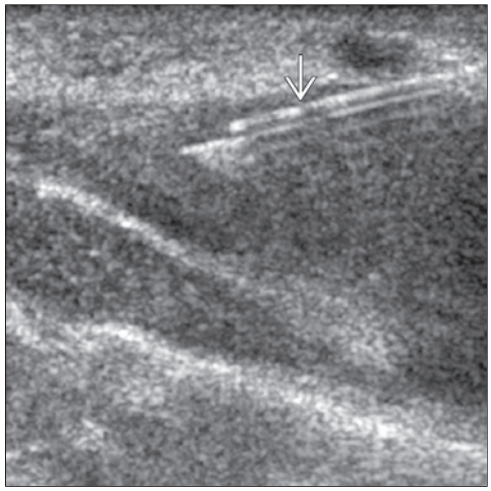






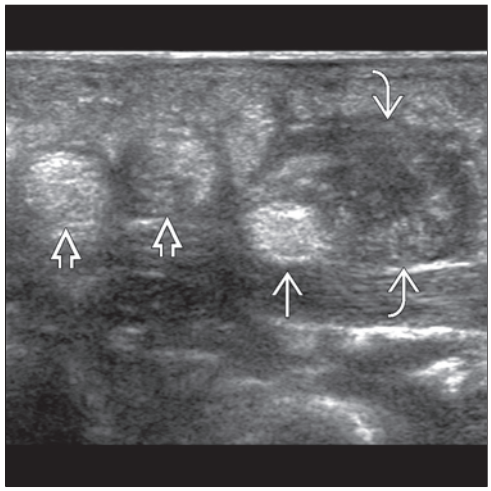
(Left) *Transverse ultrasound of the same wrist shows echogenic crystal aggregates, some of which are quite large within the thickened tenosynovium and difficult to separate from the mildly swollen tendons on this static image.* ***(Right)*** *Transverse ultrasound of the same wrist shows minimal hyperemia surrounding the extensor tendon sheath, suggestive of inactive chronic tenosynovitis.*





(Left) *Longitudinal ultrasound shows acute exudative flexor tenosynovitis of the middle finger with distension of the flexor digitorum tendon sheath by fluid containing many small echogenic aggregates, which tend to be less echogenic than those seen in gout. The flexor tendons are slightly swollen.* ***(Right)*** *Longitudinal ultrasound of the same distended tendon sheath as previous image shows needle during needle aspiration of purulent tendon sheath fluid. This tendon sheath aspirate grew Staphylococcus aureus.*

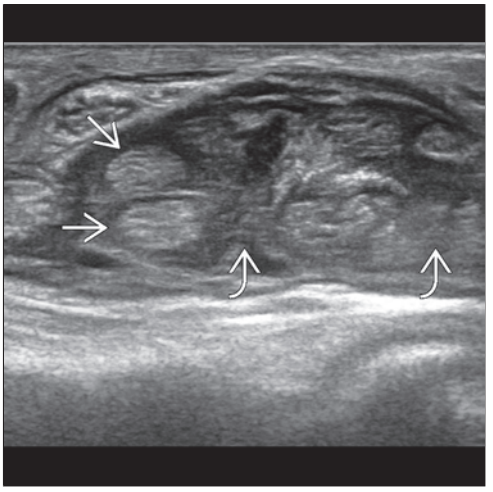


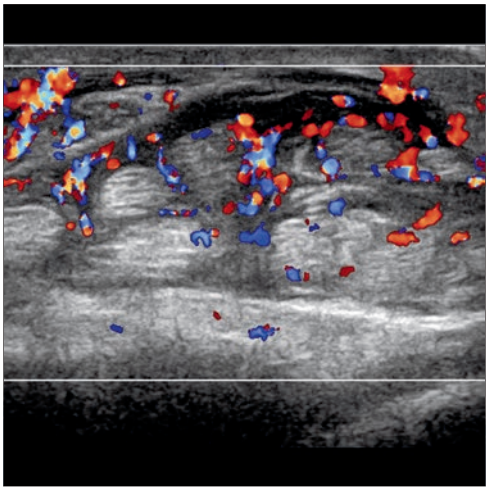


(Left) *Clinical photograph of a palm shows swelling and redness localized to the radial aspect of the palm. Ultrasound was requested to rule out deep abscess.* ***(Right)*** *Transverse ultrasound of the palm of the same patient shows thickened tenosynovium with hyperemia (not shown) eccentrically surrounding the index finger flexor tendon with moderate soft tissue swelling and edema, consistent with active chronic tenosynovitis. The remaining flexor tendons are not affected.*

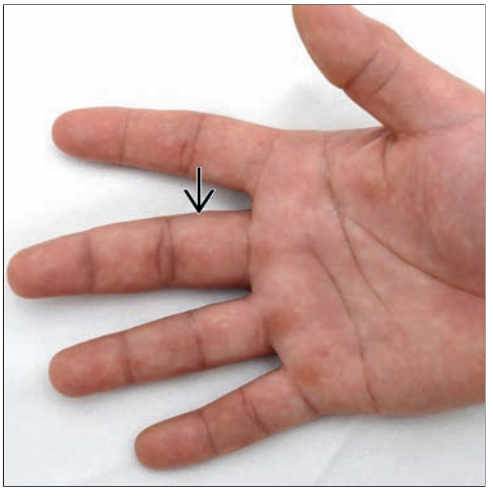
TENOSYNOVITIS

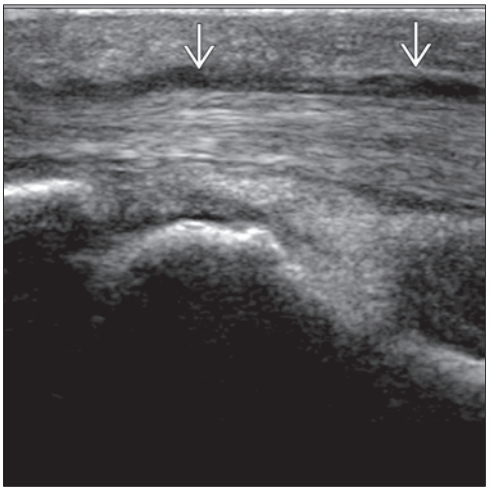
(Left) *Transverse ultrasound shows synovial proliferation* ➔ *around the flexor tendons immediately proximal to the carpal tunnel inlet. No tendon sheath fluid is present. The flexor tendons* ➔ *are slightly swollen but otherwise normal.* ***(Right)*** *Transverse color Doppler ultrasound at the same location shows severe hyperemia, predominantly located within the thickened tenosynovium, indicative of active chronic tenosynovitis.*



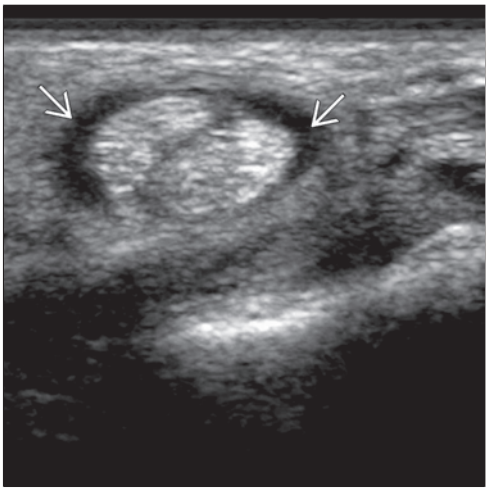


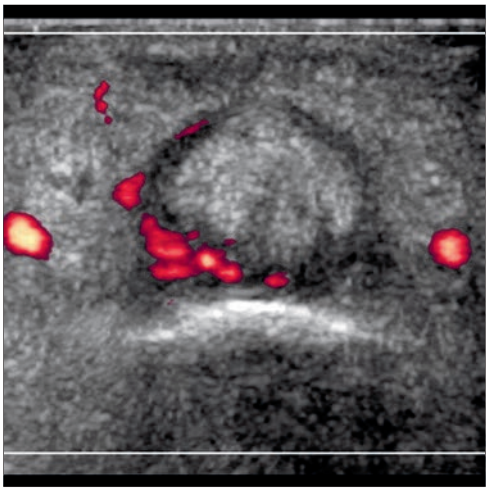
(Left) *Clinical photograph shows moderate swelling* ➔ *of the middle finger. Limited movement was present.* ***(Right)*** *Longitudinal ultrasound of the same finger shows tenosynovitis of the flexor digitorum tendon with a mildly thickened tendon sheath* ➔ *encasing the tendon. The tendon is mild to moderately thickened.*

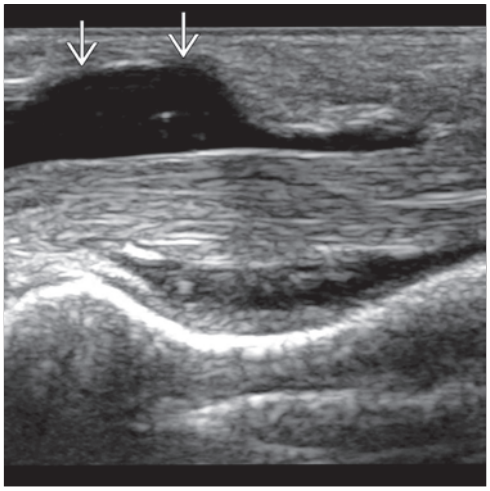


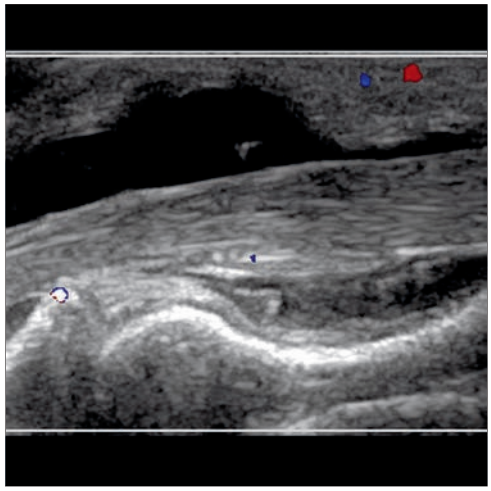


(Left) *Transverse ultrasound of the same finger shows moderate tendon sheath thickening* ➔ *encasing the flexor tendons. It is not clear whether this represents fluid or synovial proliferation.* ***(Right)*** *Transverse color Doppler ultrasound at the same location shows moderate tenosynovial hyperemia, indicating that this tendon sheath thickening is due to synovial proliferation and not fluid.*

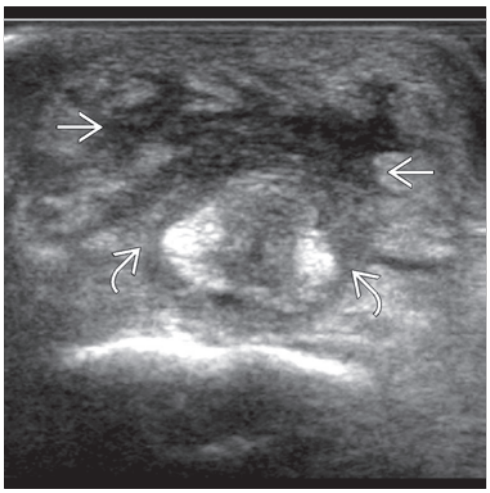


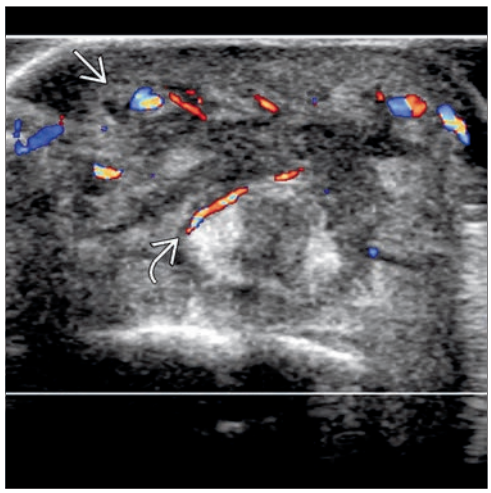




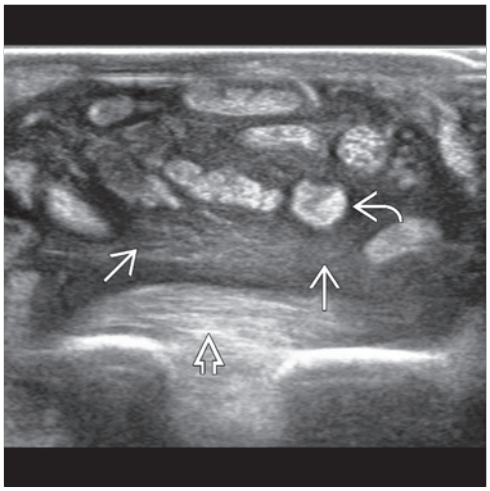


(Left) *Longitudinal ultrasound of the flexor digitorum of the ring finger in a patient with lymphoma shows a moderate amount of fluid present within the tendon sheath ➔. Ultrasound-guided aspiration yielded gelatinous content, consistent with inactive chronic tenosynovitis.* ***(Right)*** *Longitudinal color Doppler ultrasound at the same location shows no significant hypervascularity, consistent with inactive chronic tenosynovitis.*





(Left) *Transverse ultrasound of the index finger shows flexor tendon sheath effusion ➔ and severe edema of the adjacent subcutaneous tissues ➔ on the palmar aspect of the tendon sheath. This is consistent with acute flexor tenosynovitis with recent tendon sheath rupture.* ***(Right)*** *Transverse color Doppler ultrasound at the same location shows moderate hyperemia of the peritendinous soft tissues ➔ and tenosynovium ➔.*

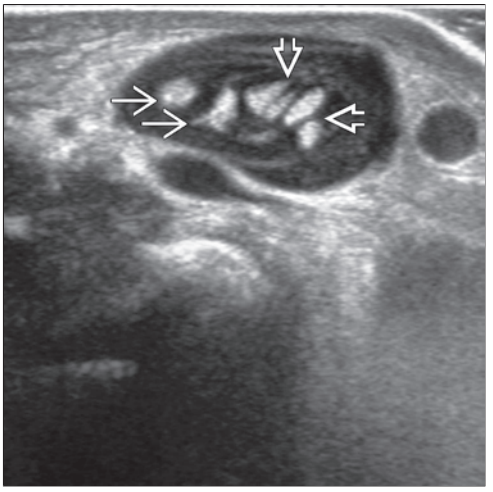


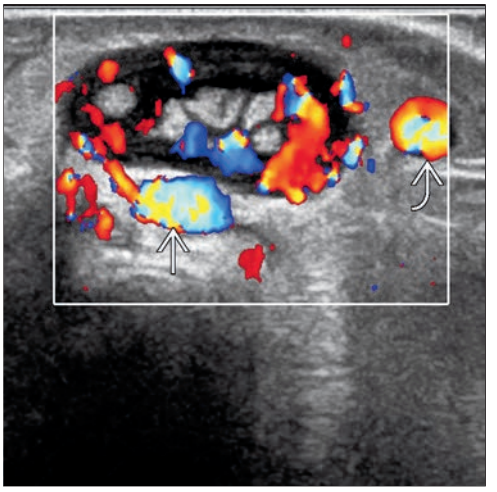


(Left) *Transverse ultrasound shows severe tenosynovial proliferation ➔ of the wrist flexor tendons in a patient with known tuberculous (TB) tenosynovitis. Color Doppler imaging (not shown) revealed marked tenosynovial hyperemia. The tendons ➔ are mildly swollen and of normal echogenicity. Pronator quadratus muscle ➔ is normal.* ***(Right)*** *Transverse ultrasound of the same wrist just distal to the previous image shows inflamed tenosynovium extending along a recent surgical incision tract ➔ toward the skin ➔.*

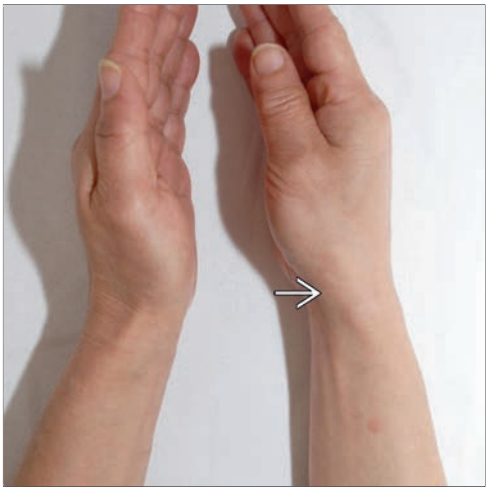
TENOSYNOVITIS

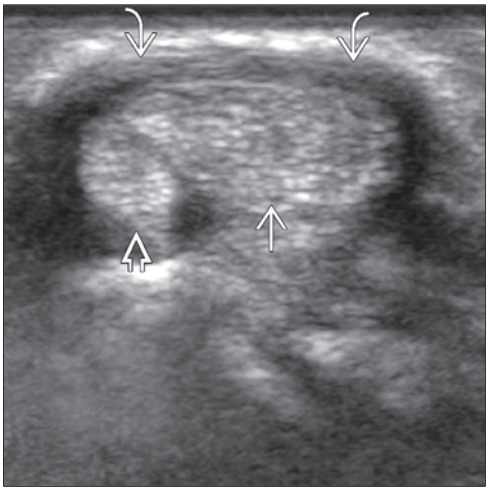
(Left) *Transverse ultrasound of the same patient shows TB tenosynovitis of the 1st extensor compartment. Both the extensor pollicis brevis and abductor pollicis longus tendons have split longitudinally with interdigitation of inflamed synovium.* ***(Right)*** *Transverse color Doppler ultrasound of the same area shows severe tenosynovial hyperemia. The main radial artery passing deep to the 1st extensor compartment tendons and the superficial palmar branch of the radial artery are shown.*



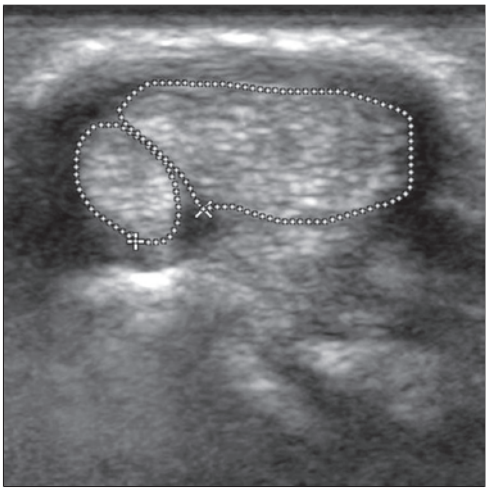


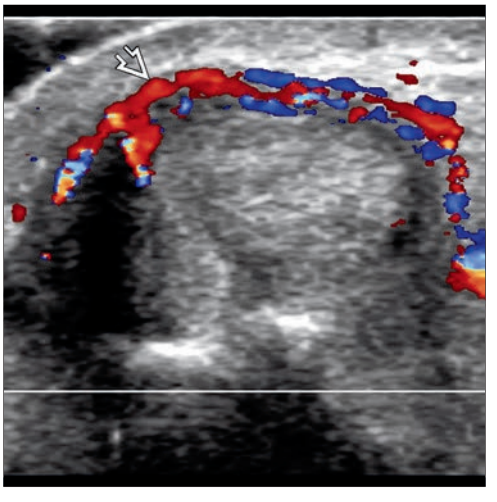
(Left) *Clinical photograph shows moderate swelling of the 1st extensor compartment tendons on the right side.* ***(Right)*** *Transverse ultrasound of the 1st extensor compartment shows a thickened abductor pollicis longus tendon and, to a lesser degree, a thickened extensor pollicis brevis tendon. The overlying extensor retinaculum is also moderately thickened. These features are compatible with de Quervain disease.*

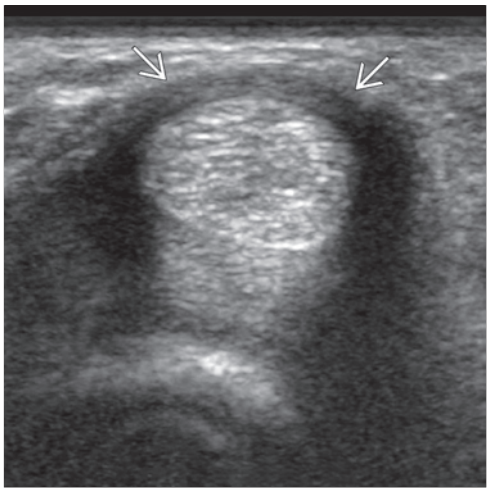


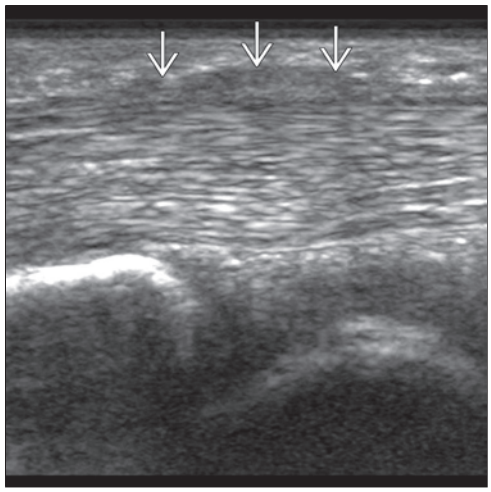


(Left) *Transverse ultrasound at the same level shows a cross-sectional area measurement using a continuous trace (dotted lines) of the 1st extensor compartment tendons. These measurements are helpful in monitoring response to treatment.* ***(Right)*** *Transverse color Doppler ultrasound at the same location shows severe hyperemia of the thickened extensor retinaculum, consistent with active inflammation.*

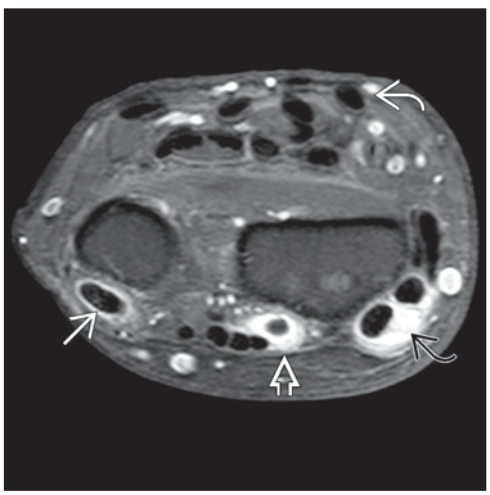


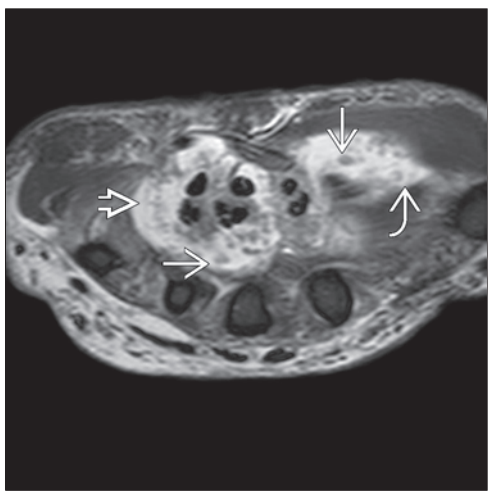






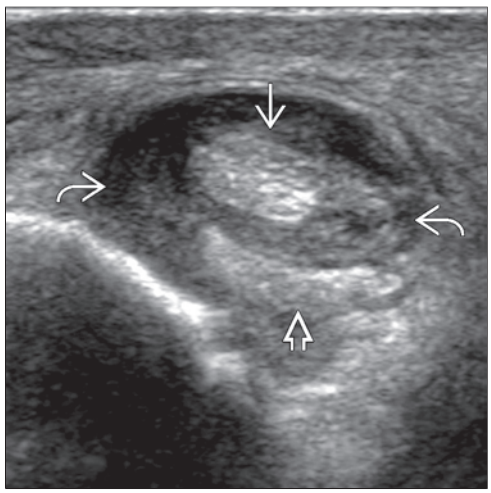
(Left) *Transverse ultrasound of a middle finger in a patient with trigger finger shows severe thickening of the A1 pulley overlying the flexor digitorum tendon. The underlying flexor tendons, which are inseparable from each other, are mildly swollen.* ***(Right)*** *Longitudinal ultrasound at the same location shows severe thickening of the A1 pulley. The underlying flexor tendons are mildly swollen and showed restriction of passive movement on dynamic testing.*





(Left) *Axial T1WI C+ FS MR in a patient with rheumatoid arthritis (RA) shows 2nd extensor compartment (ECRB and ECRL), extensor indicis, and extensor carpi ulnaris (ECU) tenosynovitis. The most commonly inflamed tendons in RA are the ECU and flexor carpi radialis (FCR), though the latter is normal in this patient.* ***(Right)*** *Axial T2WI FS MR of the wrist in a patient with SLE shows many small isointense rice bodies within distended ulnar and radial bursae (tendon sheaths). Fibrinous rice bodies are a feature of chronic tenosynovitis.*





(Left) *Clinical photograph shows lateral retromalleolar ankle swelling with a thickened tubular structure in line with the peroneal tendons.* ***(Right)*** *Transverse ultrasound of the supramalleolar common peroneus tendon sheath shows severe synovial proliferation surrounding the mildly swollen peroneus longus and peroneus brevis tendons. These features are suggestive of chronic tenosynovitis. No tendon sheath effusion is evident.*

ELBOW EPICONDYLITIS

Key Facts

Terminology
- Tennis elbow (lateral epicondylitis), golfer's elbow (medial epicondylitis)

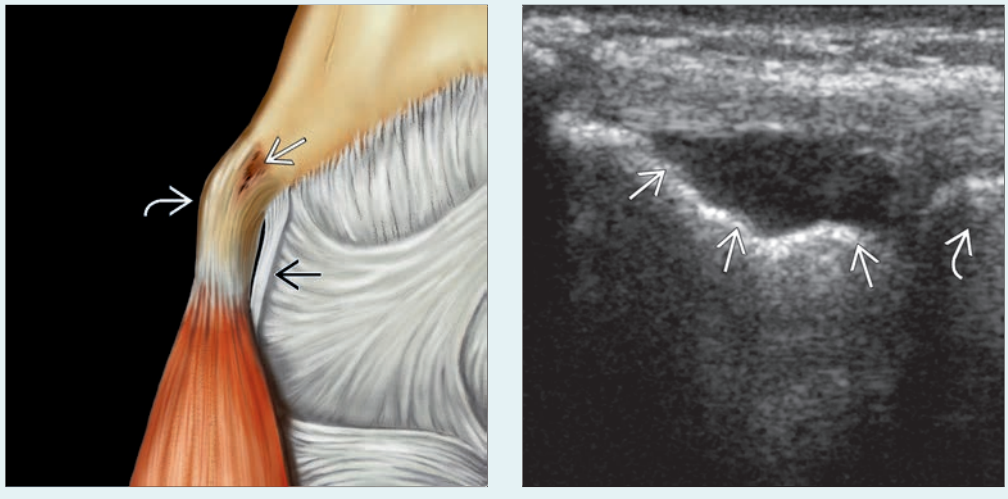
Imaging
- Thickening, hypoechogenicity, fibrillar disruption ± hyperemia of common extensor tendon origin (CETO) or common flexor tendon origin (CFTO)
  - Grade tendinosis severity (minimal, mild, moderate, severe) as this relates to likelihood of tear/long-term prognosis
  - Independently grade level of hyperemia (minimal, mild, moderate, severe); relates to disease activity
- Hypoechoic roundish areas with internal echoes indicative of focal proteoglycan deposition
- Sharp, linear hypoechoic areas within tendon indicative of intrasubstance tendon tears
- Deeper, anechoic areas indicative of avulsive-type tear
- CETO tendinosis: Usually 1st affects ECRB followed by anterior fibers of EDC
- CFTO tendinosis: Tendinosis usually 1st affects FCR, pronator teres, & palmaris longus tendons

Top Differential Diagnoses
- Cubital tunnel syndrome

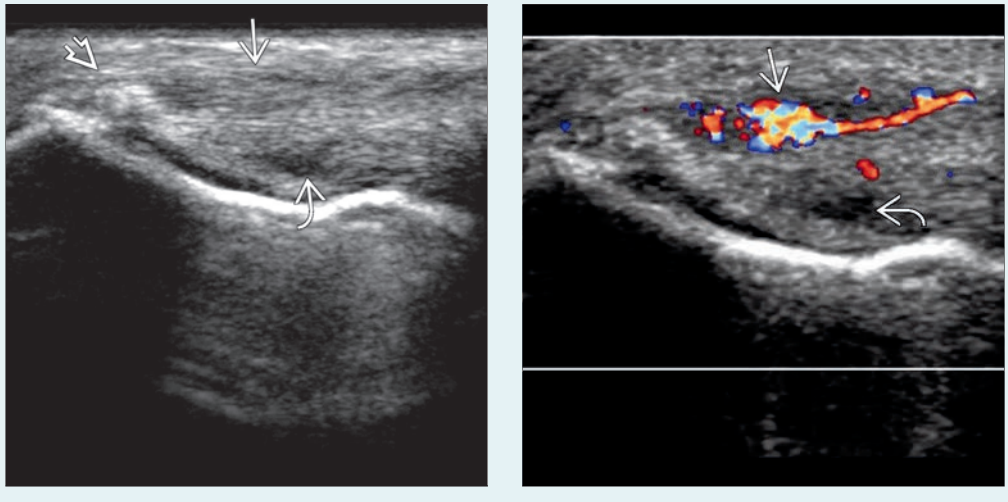
Clinical Issues
- Lateral epicondylitis is the most common cause of elbow pain
- Lateral epicondylitis is 20x more common than medial epicondylitis

Diagnostic Checklist
- Ligament injury if post-traumatic onset
- Look to deep margin of tendon for small tendon tears
- Severe pain or acute exacerbation is usually due to tendon tear

(Left) *Longitudinal graphic shows moderate severity common extensor tendon origin tendinosis* ⇒ *(lateral epicondylitis or tennis elbow) with a small tear (avulsion)* ⇒ *at the insertion into the lateral epicondyle. The radial collateral ligament* → *is normal.* ***(Right)*** *Longitudinal ultrasound shows a large tear (avulsion)* ⇒ *of the common extensor origin from the lateral epicondyle. Only the superficial fibers remain intact. The radial head* ⇒ *is normal.*



(Left) *Longitudinal ultrasound shows moderate tendinosis* ⇒ *of the common extensor tendon insertion. There is a small deep-seated intrasubstance tear* ⇒*. Early dystrophic tendon calcification* ⇒ *is present. It is important to grade tendinosis severity as minimal, mild, moderate, or severe, since this relates to the likelihood of tear.* ***(Right)*** *Longitudinal color Doppler ultrasound of the same patient shows mild hyperemia* ⇒ *indicative of active disease. The small tear* ⇒ *is also shown.*



ELBOW EPICONDYLITIS

TERMINOLOGY

Synonyms
- Tennis elbow: Lateral epicondylitis, lateral epicondylalgia
- Golfer's elbow: Medial epicondylitis, medial epicondylalgia

Definitions
- Tendinosis of chronic extensor tendon origin (CETO) (lateral epicondylitis)
- Tendinosis of chronic flexor tendon origin (CFTO) (medial epicondylitis)

IMAGING

General Features
- Best diagnostic clue
  - Rather similar appearances irrespective of whether common extensor or flexor tendon origin is affected
    - Features of tendinosis of tendon origin (hypoechogenicity, thickening, loss of normal fibrillar structure) with hyperemia
      - Tendinosis is strongly associated with tendon tears
- Location
  - Common extensor tendon origin at lateral epicondyle
    - Tendinosis usually 1st affects extensor carpi radialis brevis (ECRB) tendon followed by anterior fibers of extensor digitorum communis (EDC) tendon
    - ± tear of underlying radial collateral ligament
  - Common flexor tendon origin at medial epicondyle
    - Tendinosis usually 1st affects flexor carpi radialis (FCR), pronator teres (PT), and palmaris longus (PL) tendons
- Size
  - Varies from fibrillar disruption to tendon thickening to intrasubstance tear to complete avulsion
- Morphology
  - Diffuse tendon thickening to tear or avulsion
    - Smaller tears tend to be linear and intrasubstance in type, while larger tears tend to be avulsive in type

Radiographic Findings
- Radiography
  - Cortical irregularity and hyperostosis of common tendon origin area
  - Dystrophic calcification within common tendon origin
  - Soft tissue swelling at common tendon origin

MR Findings
- T1WI
  - Thickening and increased signal intensity within common extensor (or flexor) tendon origin at the lateral (and medial) epicondyle respectively
- T2WI FS
  - Thickening and increased signal intensity of common extensor (of flexor) tendon origin
    - Peritendinitis is feature of more severe cases
    - Insertional subcortical bone marrow edema not usually seen

Ultrasonographic Findings
- Tendinosis (> 90% of symptomatic subjects)
  - Thickened, hypoechogenic tendon with surface bowing and disruption of normal fibrillar pattern
    - Tendon hypoechogenicity usually affects deeper aspects of tendon initially, spreading to more superficial aspects as disease progresses
    - Ill-defined hypoechoic areas are indicative of focal proteoglycan accumulation
    - Increased cross-sectional area and thickness of tendon
    - For lateral epicondylitis, average (range)
      - Cross-sectional area: 44 mm² (35-55 mm²) for patients vs. 26 mm² (17-35 mm²) for normal subjects; > 32 mm² highly predictive of lateral epicondylitis
      - Thickness: 4.9 mm (3.9-6.0 mm) for patients vs 3.0 mm (2.0-3.7 mm) for normal subjects; > 4.2 mm highly predictive of lateral epicondylitis
- Tendon hyperemia (60% of symptomatic subjects)
  - Normal tendons do not display intrinsic vascularity
- Tendon tears (20% of symptomatic subjects)
  - Sharp, linear hypoechoic areas within tendon are indicative of intrasubstance tendon tears
    - Deeper, anechoic areas indicative of avulsive-type tear
- Secondary signs of tendinosis
  - Dystrophic calcification within tendon substance (30% of symptomatic subjects)
  - Cortical irregularity at insertional area (20% of symptomatic subjects)
  - Calcific enthesophytes at insertional area (45% of symptomatic subjects)
- Radial collateral ligament can be injured with more advanced lateral epicondylitis
- Sonoelastography may be helpful in diagnosis of lateral epicondylitis (100% sensitivity, 89% specificity reported)
- Patients may have characteristic symptoms of epicondylitis but no abnormality on ultrasound
  - Conversely, patients may have no symptoms of epicondylitis and mild to moderate common extensor (or flexor) tendinosis on ultrasound

Imaging Recommendations
- Best imaging tool
  - Ultrasound
- Protocol advice
  - Examination with shoulder elbow flexed; elbow internally rotated for lateral epicondylitis, externally rotated for medial epicondylitis
    - Examine with transducer aligned both parallel to and at right angles to long axis of tendons
    - Measure cross-sectional area and thickness of tendon at flat lateral aspect of lateral epicondyle (for lateral epicondylitis)
  - Always include evaluation with color Doppler and compare with contralateral side
    - Grade vascularity subjectively as absent, minimal, mild, moderate, or severe
    - Level of hyperemia is a good guide as to level of disease activity
  - Consider MR if ultrasound findings do not explain patient symptoms

ELBOW EPICONDYLITIS

DIFFERENTIAL DIAGNOSIS

Cubital Tunnel Syndrome
- Compression of ulnar nerve in cubital tunnel
- Inflammation of ulnar nerve may occur with medial epicondylitis

Hypertrophy of Radiohumeral Synovial Flange
- Synovial fold projecting into posterolateral aspect of elbow joint
- Fold can hypertrophy with repetitive pronation and supination
  - Symptomatic folds show hypertrophy and increased innervation

Radial Collateral Ligament Injury
- Usually history of moderate to severe trauma

PATHOLOGY

General Features
- Etiology
  - Overload injury, typically after minor and often unrecognized injury
- **Relevant anatomy: Common extensor tendon origin**
  - ECRB, EDC, extensor digiti minimi (EDM), and extensor carpi ulnaris (ECU) (humeral head) all arise from lateral epicondyle
    - ECRB, EDC & EDM have a common origin from the superior aspect of the lateral epicondyle
    - ECU arises from posteroinferior aspect of the lateral epicondyle and lies deep to EDC and EDM tendons
  - ECRL arises from supracondylar ridge separate from common extensor tendon origin
  - Lateral collateral ligament lies deep to the extensor tendons and runs in a slightly different direction
    - Bursa may exist between extensor tendons and lateral collateral ligament at elbow joint
- **Relevant anatomy: Common flexor tendon origin**
  - Pronator teres, FCR, flexor digitorum superficialis (FDS), palmaris longus, and FCU all arise from medial epicondyle
    - FDS lies deep to FCR, palmaris longus, and flexor carpi ulnaris (FCU)

Staging, Grading, & Classification
- Classify as mild, moderate, or severe, depending on overall severity of tendinosis ± tears

Gross Pathologic & Surgical Features
- Tendinosis with tendon thickening ± macroscopic partial tear or full thickness tear

Microscopic Features
- Angiofibroblastic degeneration with disrupted collagen fibers, neovascularization, and tenocyte proliferation
  - Tendon tears heal with reparative granulation tissue
  - Maturation of fibrous tissue to scar-like tendon tissue
- Epicondylitis is not an inflammatory condition, though peritendinitis is a feature
- Pathology is similar for both medial and lateral epicondylitis

CLINICAL ISSUES

Presentation
- Most common signs/symptoms
  - Adult patient with lateral or medial elbow pain
    - Pain aggravated by vigorous exercise, gradually lessens with rest over several days
    - Lateral epicondylitis is aggravated by forced wrist extension; medial epicondylitis is aggravated by forced wrist flexion
    - Local tenderness at tendon origin

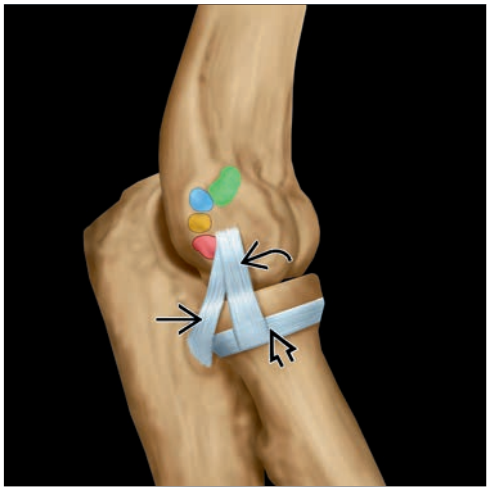
Demographics
- Age
  - Peak incidence: 40-50 years
- Epidemiology
  - Population prevalence ~ 3%
  - Lateral epicondylitis is the most common cause of elbow pain
    - 20x more common than medial epicondylitis
      - Most patients with tennis elbow do not play tennis
      - Tennis elbow is more common in golfers than golfer's elbow

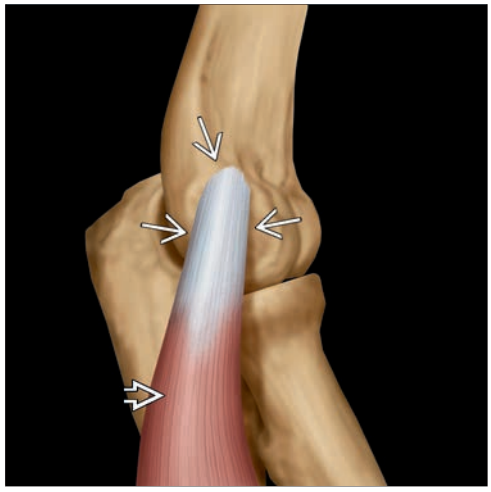
Natural History & Prognosis
- Usually self-limiting; 1/3 will improve by 3 months, 1/2 by 6 months, 3/4 by 1 year
  - Chronic symptoms or relapse more likely if established tendinosis on ultrasound

Treatment
- Conservative
  - Most patients respond to rest ± bracing
    - ± physiotherapy, exercise, stretching
    - ± nonsteroidal anti-inflammatory medication (oral or topical)
- Many additional treatments for refractory cases
  - Limited evidence currently to recommend any particular method over another
    - Corticosteroid therapy: Short-term benefit but likelihood of long-term harm
      - Iontophoresis (drug such as corticosteroid introduced through skin using electric charge)
    - Ultrasound-guided: Dry needling, autologous blood injection, platelet-rich plasma injection
    - Other treatments: Extracorporeal shock wave therapy, pulsed low-intensity ultrasound (LIUS), pulsed electromagnetic field therapy, low-level laser therapy
- Surgical
  - Anchoring of tendon insertion or tendon release

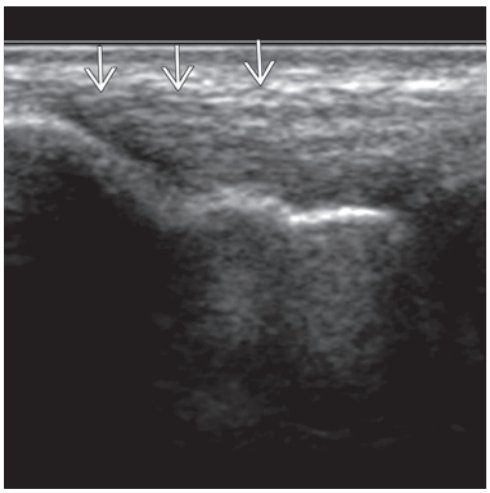
SELECTED REFERENCES

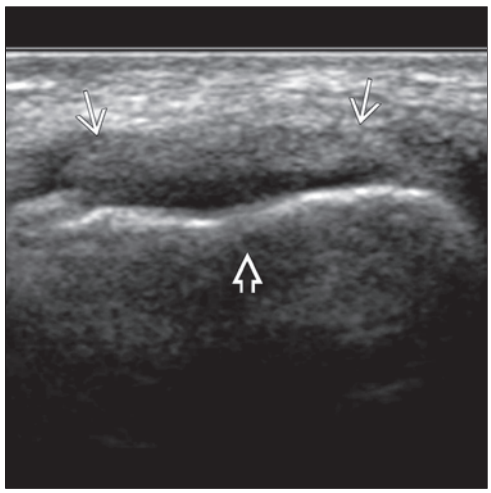
1. Connell DA et al: Ultrasound-guided autologous blood injection for tennis elbow. Skeletal Radiol. 35(6):371-7, 2006





(Left) *Schematic diagram shows the attachment of common extensor tendons at the lateral epicondyle (green = extensor carpi radialis brevis; blue = extensor digitorum; yellow = extensor digiti minimi; red = extensor carpi ulnaris) and lateral collateral ligaments (radial collateral ligament, lateral ulnar collateral ligament, and annular ligament). **(Right)** Schematic diagram shows the common extensor attachment at the lateral epicondyle. Note the extensor muscle fibers.*





(Left) *Longitudinal ultrasound shows the normal common extensor tendon origin (CETO) at the lateral humeral epicondyle. There is no abnormal thickening or tear. The fibrillar pattern of the tendon is preserved. **(Right)** Transverse ultrasound of the same patient shows the normal CETO on the flat portion of the lateral humeral condyle. This is the area where the cross section of the common extensor tendons can be measured.*

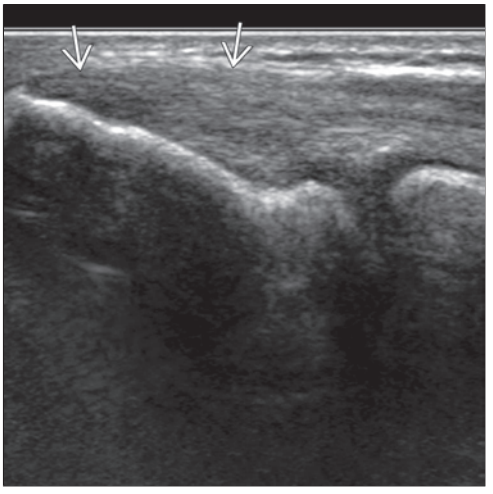


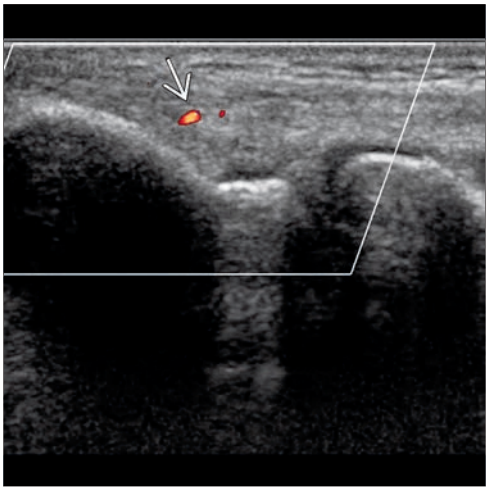


(Left) *Transverse ultrasound shows measurement of the cross-sectional area of the common extensor tendon just proximal to the bony attachment. Such measurements are useful for follow-up and for broadly gauging severity of disease. **(Right)** Coronal T2WI FS MR shows normal CETO from the lateral epicondyle. There is no abnormal hyperintense signal or fiber discontinuity (tear). A small amount of normal physiological joint fluid is present at the radiocapitellar articulation.*

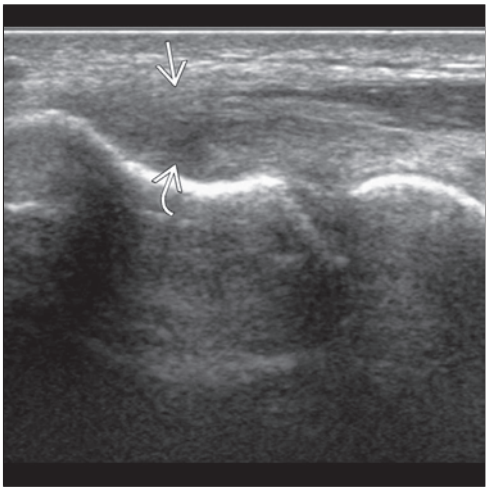
ELBOW EPICONDYLITIS

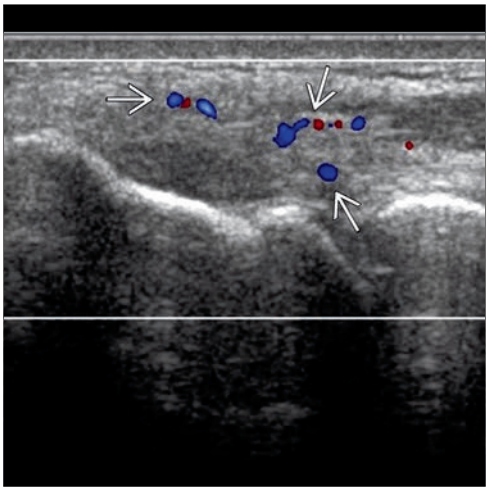
(Left) *Longitudinal ultrasound shows mild thickening of the CETO ➔ at the lateral epicondyle, indicative of mild tendinosis.* ***(Right)*** *Longitudinal color Doppler ultrasound of the same patient shows only minimal hyperemia ➔ indicative of minimal disease activity. Tendinosis around the elbow should be routinely assessed with color Doppler imaging, as this provides the best indication of disease activity. Normal tendon do not show color flow.*



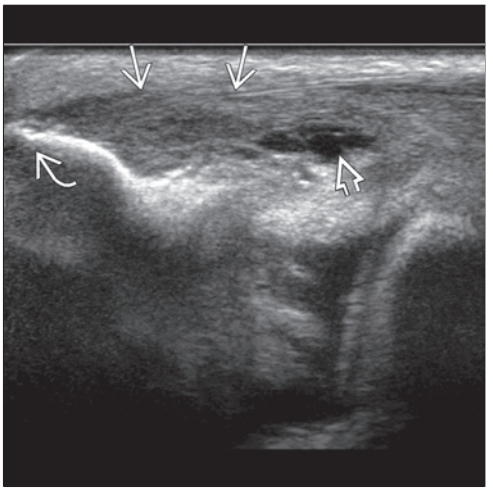


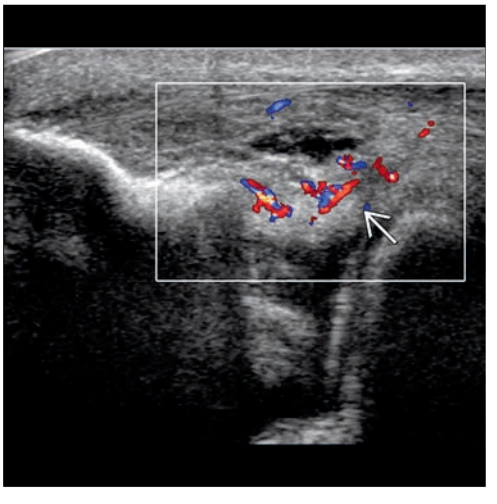
(Left) *Longitudinal ultrasound shows mild thickening of the CETO ➔ at the lateral epicondyle, indicative of mild tendinosis. The ill-defined area of increased hypoechogenicity ➔ is due to proteoglycan accumulation rather than an intrasubstance tear.* ***(Right)*** *Longitudinal color Doppler ultrasound of the same patient shows mild hyperemia ➔, indicative of mildly active disease.*

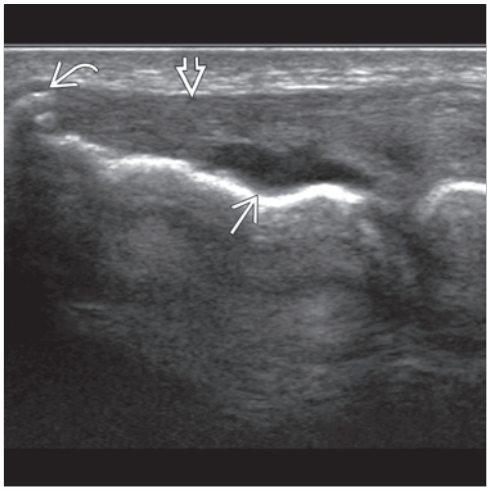


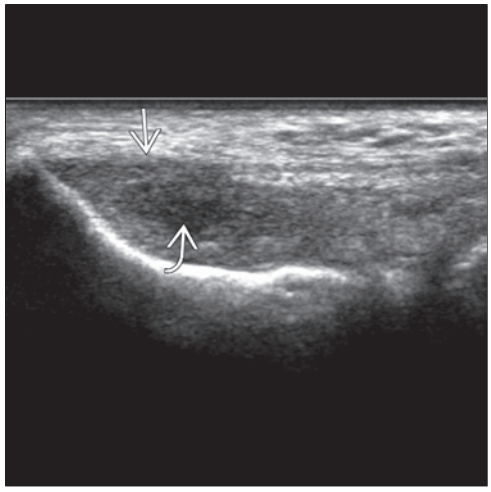


(Left) *Lateral ultrasound shows moderate thickening and hypoechogenicity of the CETO ➔ at the lateral epicondyle, indicative of moderate tendinosis. There is medium-sized intrasubstance tendon tear ➔. Mild insertional cortical hyperostosis ➔ is present.* ***(Right)*** *Longitudinal color Doppler ultrasound of the same patient shows mild to moderate hyperemia ➔ indicative of active disease.*

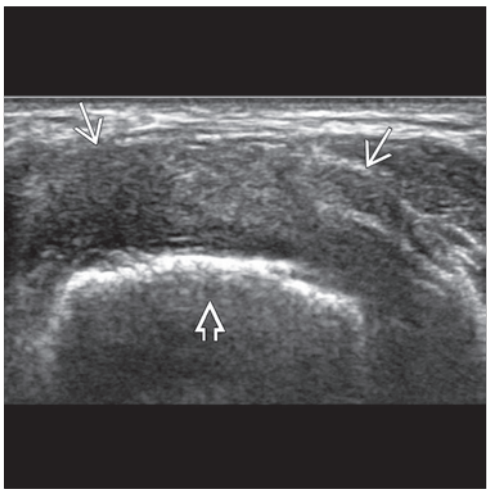


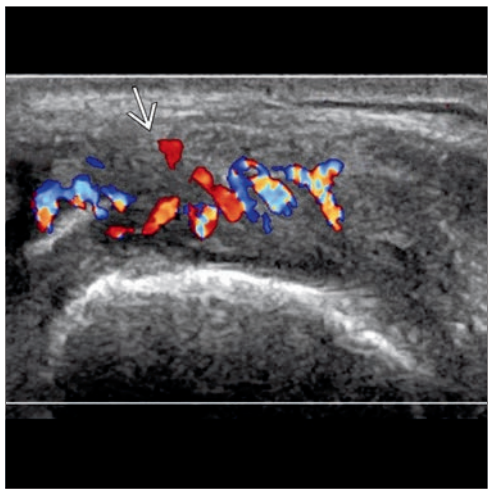




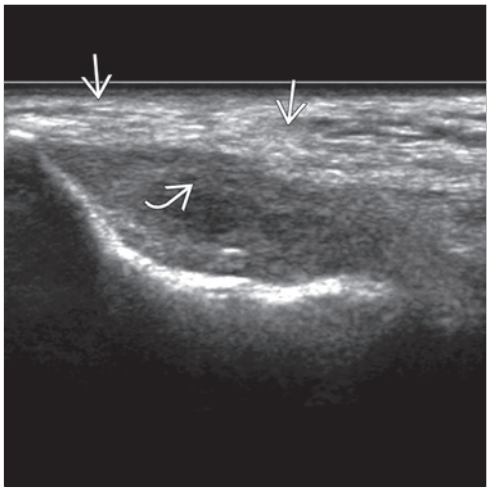


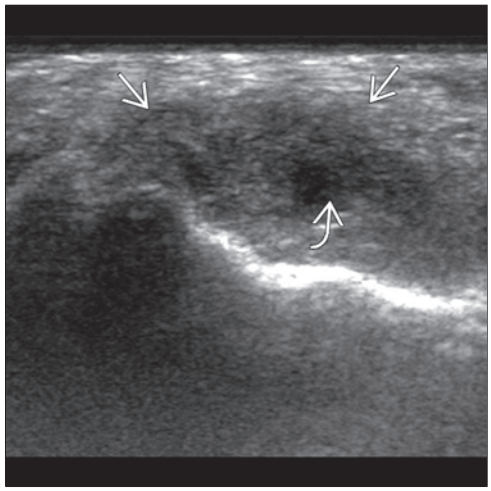
(Left) *Longitudinal ultrasound shows mild tendinosis of the CETO with hypoechogenicity and loss of fibrillar pattern. There is a medium-sized tear (avulsion) of the deeper part of the tendon insertion. Mild insertional cortical hyperostosis is present.* ***(Right)*** *Longitudinal ultrasound shows moderate tendinosis of the CETO associated with a medium-sized central tear, as evidenced by the more pronounced hypoechogenicity.*





(Left) *Transverse ultrasound shows moderate thickening of the CETO overlying the lateral humeral condyle. No tear is present.* ***(Right)*** *Transverse color Doppler ultrasound of the same patient shows moderate to severe hyperemia indicative of moderate to severe disease activity. Disease activity does not invariably accompany macroscopic tendon tear and vice versa.*

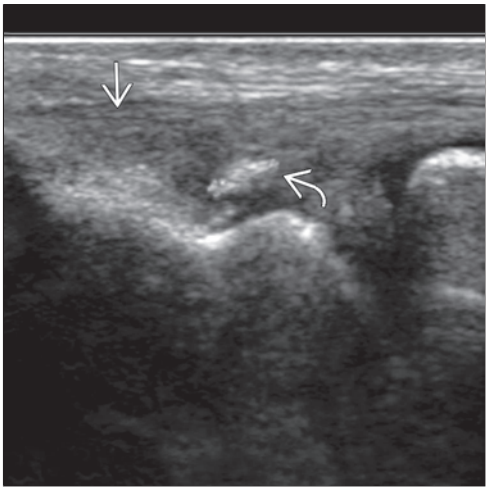




(Left) *Longitudinal ultrasound shows moderate tendinosis of the CETO with tendon thickening and hypoechogenicity associated with a small intrasubstance tear. Distinguishing between focal severe proteoglycan (mucoid) accumulation and tear is not always easy, as both entities may coexist.* ***(Right)*** *Oblique ultrasound of the same patient shows moderate CETO tendinosis with an intrasubstance tendon tear.*

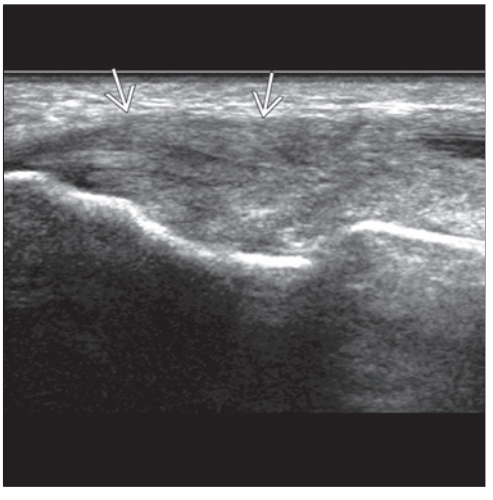
ELBOW EPICONDYLITIS

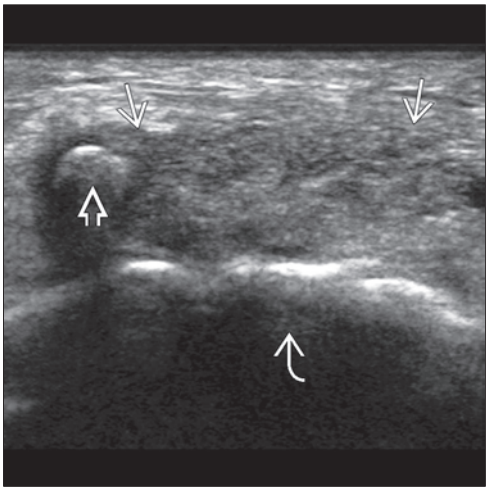
(Left) *Lateral ultrasound shows moderate tendinosis of the CETO ➔ with dystropic intratendinous calcification ➔. **(Right)** Coronal T2WI FS MR of the same patient shows abnormal thickening and hyperintense T2-weighted signal intensity ➔ of the CETO, indicative of moderate tendinosis. There is a very small intrasubstance tear present ➔. Unlike insertional tendinosis at other sites, bone marrow edema is not a common feature of CETO tendinosis.*



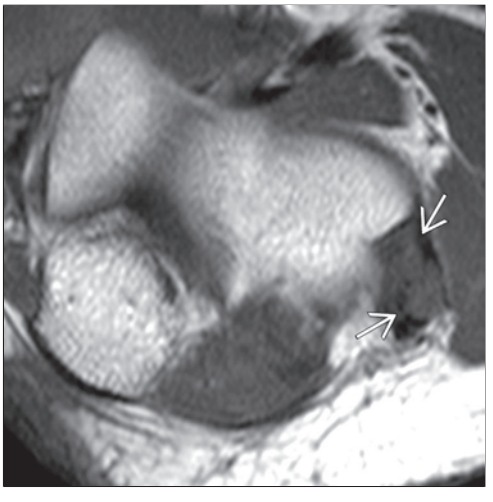


(Left) *Longitudinal ultrasound shows severe CETO ➔ with tendon thickening, hypoechogenicity, and loss of the normal fibrillar pattern. No tear is present. **(Right)** Transverse ultrasound of the same patient shows severe CETO tendinosis ➔ with dystrophic intratendinous calcification ➔. Mild surface irregularity of the lateral humeral condyle is present ➔.*

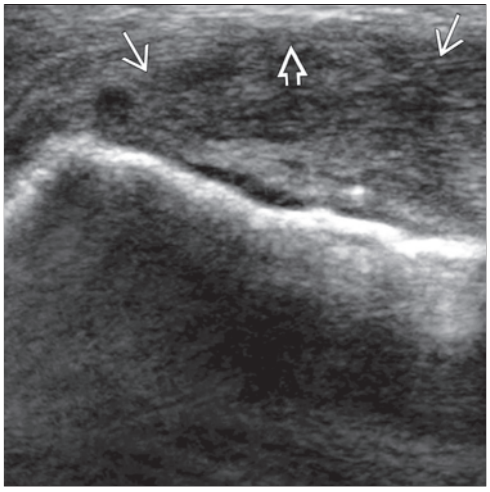


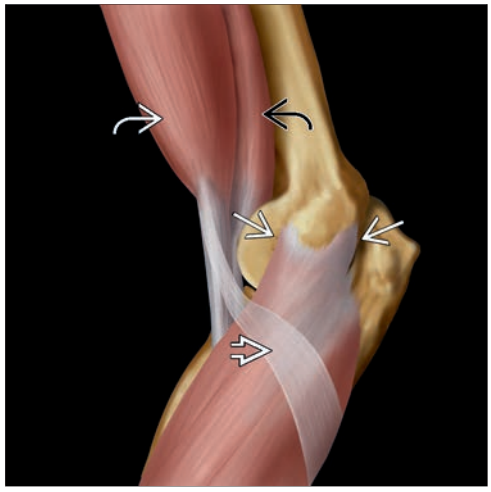


(Left) *Axial T1WI MR of the same patient shows the thickened CETO, which is isointense ➔ to adjacent muscle. **(Right)** Coronal T2WI FS MR of the same patient shows severe CETO tendinosis ➔ with diffuse hyperintensity. No tear is present. Only that portion of the CETO close to the bone is affected. There is very little reactive bone change.*

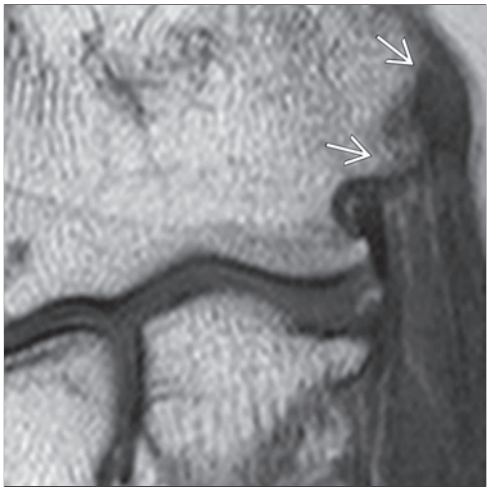


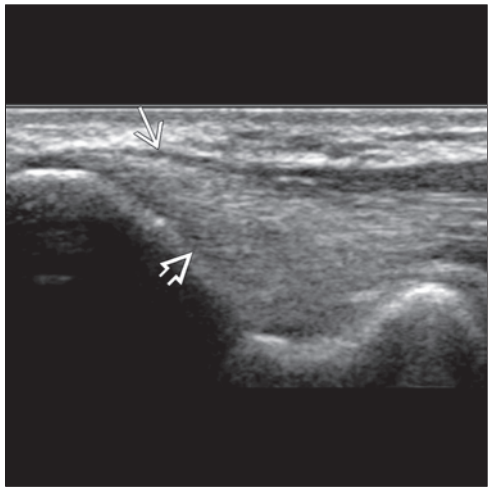




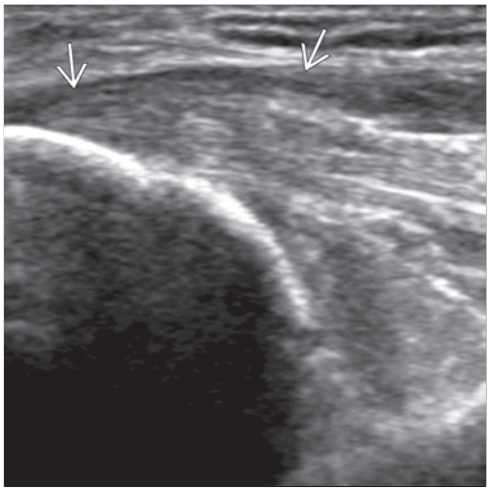


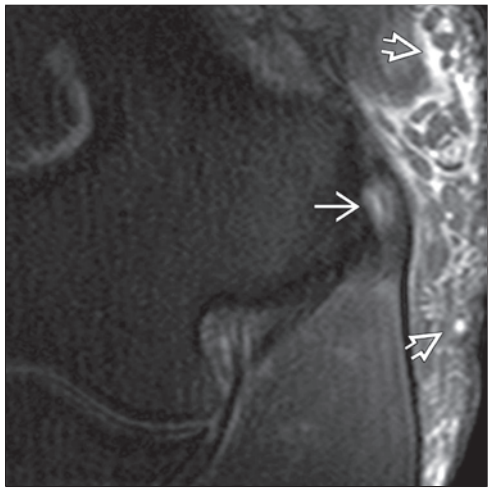
(Left) *Longitudinal ultrasound shows severe tendinosis of the CETO with a superficial bulging contour of the tendon surface.* ***(Right)*** *Schematic diagram shows the attachment of common flexor tendons at the medial epicondyle. Note the bicipital aponeurosis, biceps muscle, and brachialis muscle.*



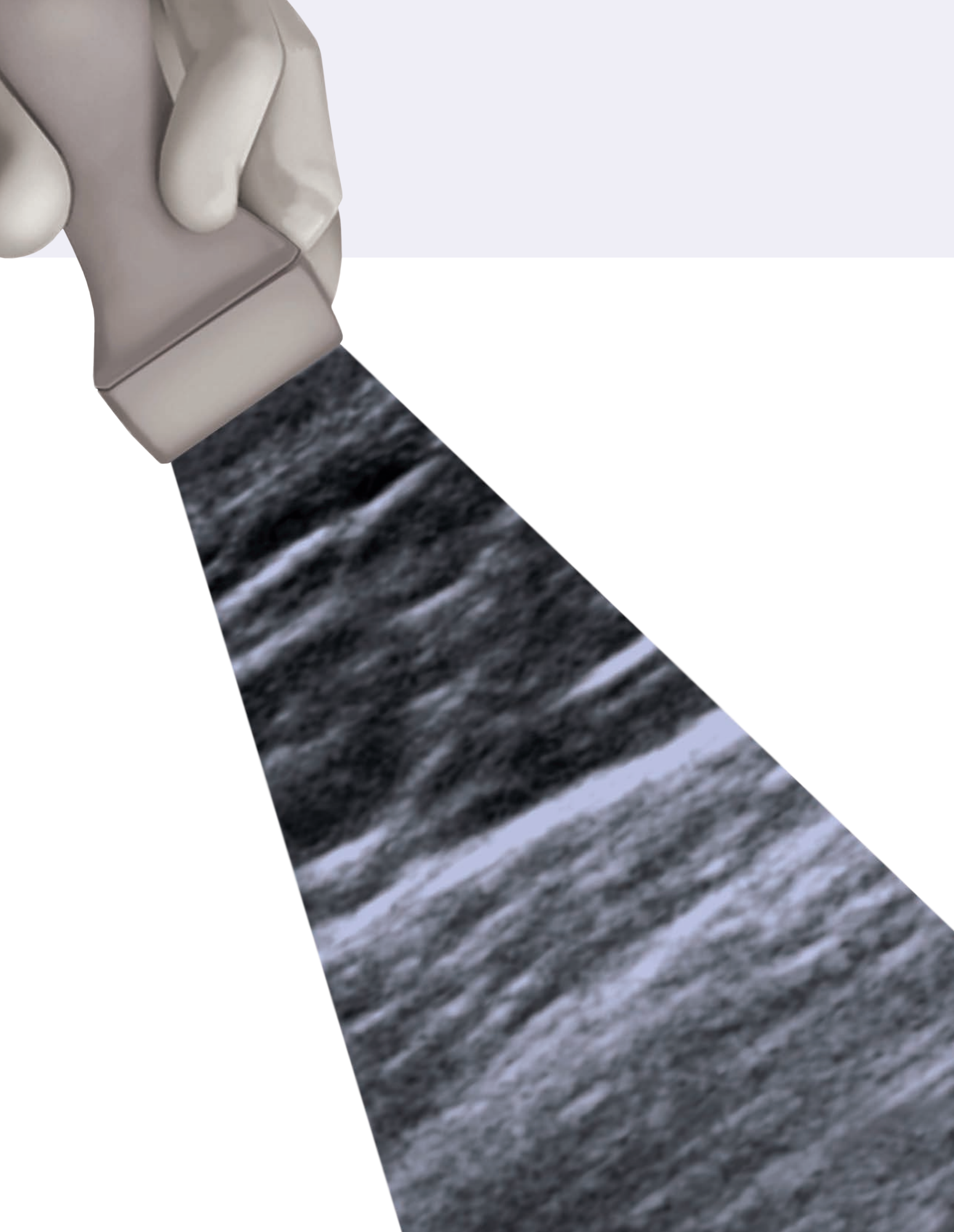


(Left) *Coronal T1WI MR shows the normal common flexor tendon origin at the medial epicondyle. The tendon is hypointense and inserted over a broader area than the CETO on the lateral side.* ***(Right)*** *Longitudinal ultrasound shows the normal common flexor tendon origin at the medial epicondyle. Note the largely flattened superficial contour.*





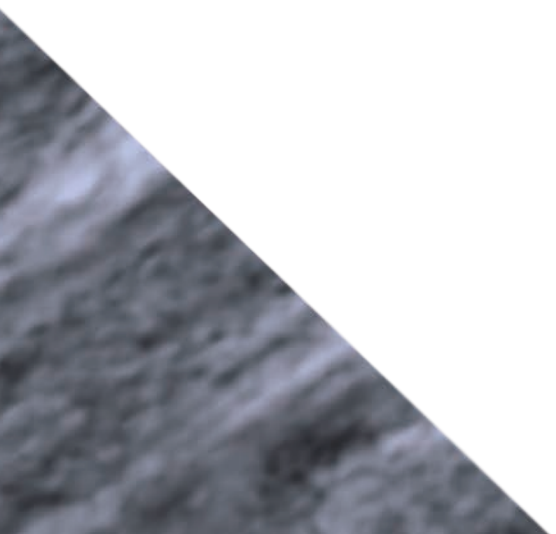
(Left) *Longitudinal ultrasound shows mild common flexor tendon origin tendinosis with hypoechogenicity and a more bulging superficial contour. No tear is apparent.* ***(Right)*** *Coronal T2WI FS MR of the same patient shows a small intrasubstance tear within the common flexor tendon origin. There is moderate adjacent subcutaneous soft tissue edema. MR is helpful if ultrasound fails to fully explain the patient's symptoms.*



SECTION 3

Soft Tissue, Bone, and Joint Injury

Fat Injury **II**-3-2
Muscle Infarction **II**-3-10
Muscle Injury **II**-3-14
Hematoma/Seroma **II**-3-24
Ligament Injury **II**-3-32
Bone Fracture **II**-3-40



FAT INJURY

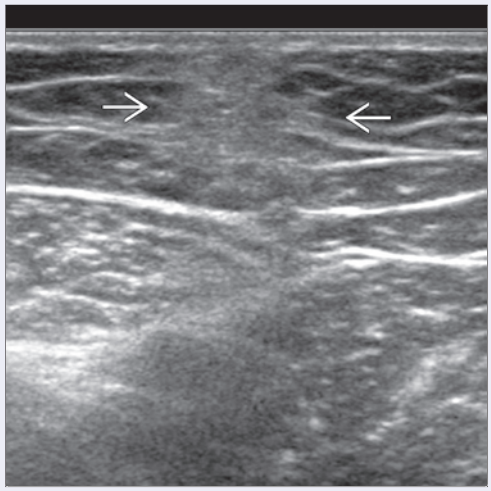
Key Facts

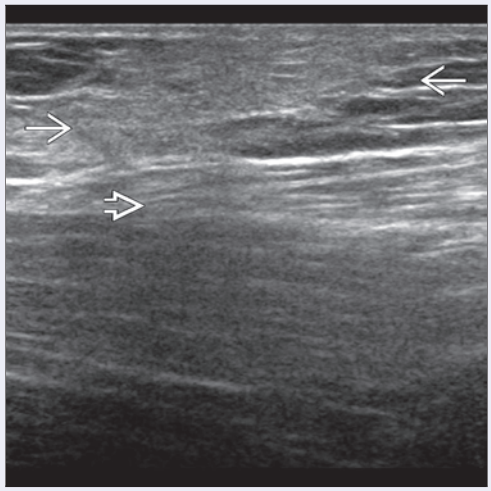
Terminology
- Focal inflammation ± necrosis ± atrophy of subcutaneous fat

Imaging
- Variable appearances, which depend on chronicity of lesion
- Localized swelling and increased echogenicity of subcutaneous fat in early stages
- Loss of normal subcutaneous fat striation
- Irregular poorly defined margins without discrete mass
- Lobulation of affected area with hypoechoic stranding extending into surrounding fat
- ± hypoechoic pseudocapsule
- ± fluid accumulation within affected fat
- ± calcification of affected fat
- Area of fat necrosis becomes better defined & more hypoechoic with increasing chronicity
- Usually fascia and muscle deep to affected area are normal
- Usually mild or no hyperemia
- Ultrasound allows definitive diagnosis in most cases
  - Ultrasound is better at depicting associated calcification than MR
- Morel-Lavallée lesion
  - Compressible hypoechoic or anechoic collection between subcutaneous fat and investing fascia
  - Most commonly occurs in anterolateral thigh

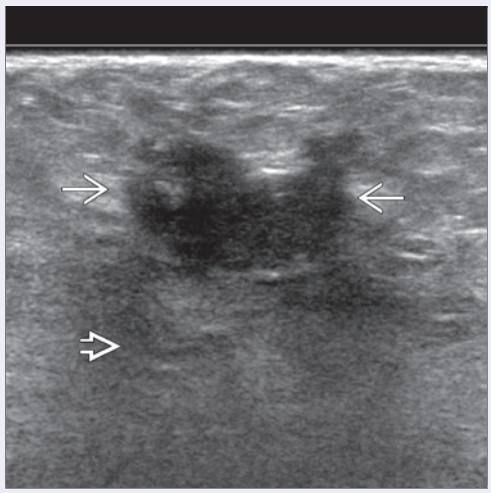
Top Differential Diagnoses
- Superficial thrombophlebitis
- Subcutaneous lipoma
- Subcutaneous panniculitis
- Subcutaneous fat necrosis of the newborn

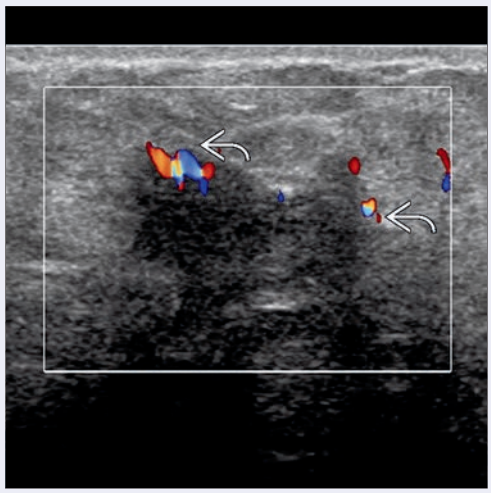
(Left) *Transverse ultrasound of the lateral thigh region in a patient with recent trauma to this area shows an ill-defined area of increased echogenicity of the subcutaneous fat* ⇨. ***(Right)*** *Longitudinal ultrasound of the same lesion shows an ill-defined area of hyperechogenicity consistent with post-traumatic subcutaneous edema* ⇨. *The entire thickness of the subcutaneous fat is involved. The signal alteration in the muscle layer may be partly or wholly artifactual* ⇨.





(Left) *Longitudinal ultrasound of a patient with an abdominal wall mass that slowly developed following trauma 1 year earlier shows a discrete, irregular, hypoechoic mass* ⇨ *in the subcutaneous fat of the anterior abdominal wall. Note the mild degree of posterior shadowing* ⇨ *due to fibrotic tissue.* ***(Right)*** *Longitudinal color Doppler ultrasound of the same lesion shows the presence of mild, marginal hyperemia* ⇨, *consequent on perilesional reparative change.*





FAT INJURY

TERMINOLOGY

Definitions
- Focal inflammation ± necrosis ± atrophy of subcutaneous fat
- Morel-Lavallée lesion: Shear stress leading to shearing of skin and subcutaneous tissue from underlying fascia with development of blood-filled hollow space

IMAGING

General Features
- Best diagnostic clue
  - Localized altered echogenicity and thickness of subcutaneous fat with loss of normal fat lobulation
- Location
  - Subcutaneous fat usually over bony protuberances
    - Mainly affects lower limbs or gluteal region
- Size
  - From a few mm to 10 cm
  - Usually full depth of subcutaneous tissue is affected
- Morphology
  - Focal swelling of subcutaneous tissues progressing to induration and atrophy

Radiographic Findings
- Focal swelling or atrophy of subcutaneous soft tissue
- Subcutaneous calcification
- Subcutaneous gas locules after high pressure trauma

MR Findings
- T1WI
  - Focal hyperintense subcutaneous fat swelling
  - Spiculated areas of linear hypointensity within subcutaneous fat due to reactive fibrosis
    - ± pseudocapsule
  - Focal atrophy of subcutaneous fat
  - Usually investing fascia and muscle are normal
- T2WI FS
  - Focal hyperintense subcutaneous fat swelling with surrounding edema
    - ± nodular areas of subcutaneous hypointensity due to calcification
    - ± larger hyperintense areas within subcutaneous fat due to fluid
- T1WI C+ FS
  - Minimal or no intrinsic contrast enhancement
  - Enhancement of pseudocapsule and surrounding edema

Ultrasonographic Findings
- Grayscale ultrasound
  - **Traumatic fat necrosis**
    - Appearances vary depending on lesion chronicity
    - Localized swelling and increased echogenicity of edematous subcutaneous fat in early disease
      - Poor definition of normal subcutaneous fat lobulation
      - Irregular poorly defined margins without discrete mass
      - Lobulation of subcutaneous fat which becomes better defined and more hypoechoic with increasing chronicity
      - ± pseudocapsule which is usually hypoechoic though may be hyperechoic
    - ± fluid accumulation within affected fat
      - Linear fluid collections located superficial to investing fascia
      - Larger, more rounded fluid collections in areas with more abundant subcutaneous fat (e.g., buttock)
    - ± calcification of affected subcutaneous fat
      - Can be seen in subacute or chronic stage of fat necrosis
      - May vary from mild, speckled calcification to dense calcification
      - Calcification is more frequent and more dense with increasing duration of disease
      - Shadowing artifact may impede full depiction of necrotic area
      - Less severe shadowing artifact in chronic lesion can result from aggregations of fibrosis without calcification
    - Hyperemia is usually mild or absent
      - More pronounced hyperemia suggests secondary infection
    - Area of subcutaneous fat necrosis becomes better defined and more hypoechoic with increasing chronicity
      - Subcutaneous fat atrophy may develop at later stage of disease
    - Usually fascia and muscle deep to affected area are normal
      - May rarely show disruption if prior trauma
  - **Morel-Lavallée lesion**
    - Uncommon lesion
    - Compressible hypoechoic or anechoic collection between subcutaneous fat and investing fascia
      - Arguably a fascial rather than fat injury
      - Most commonly occurs in anterolateral thigh
    - Acute/subacute: More heterogeneous and irregular
      - ± echogenic, nondependent fat globules within fluid collection
      - ± signs of secondary infection
    - Chronic: More homogeneous and well-defined
      - Partial or complete fibrous capsule

Imaging Recommendations
- Best imaging tool
  - Ultrasound provides definitive diagnosis in most cases with ready comparison of opposite side
    - Better at depicting associated calcification than MR
    - MR is better at defining extent at markedly edematous subcutaneous tissue
- Protocol advice
  - Minimal transducer pressure to avoid effacement of subcutaneous fat
  - Ample acoustic gel to fill any skin depression
  - Compare with adjacent normal subcutaneous fat on ipsilateral side or normal subcutaneous fat on contralateral side
  - Use color Doppler to assess vascularity
  - Extended field-of-view imaging can improve perception of localized subcutaneous fat atrophy
    - Also useful in showing full length of Morel-Lavallée lesion

FAT INJURY

DIFFERENTIAL DIAGNOSIS

Superficial Thrombophlebitis
- Localized swelling wall of subcutaneous vein
- ± perivenous edema ± intraluminal thrombosis

Subcutaneous Lipoma
- Discrete nontender lipomatous mass within subcutaneous tissues
- Fine linear striations parallel to long axis of mass
- Atypical lipoma and angiolipoma mimic fat necrosis

Subcutaneous Panniculitis
- Localized subcutaneous inflammation with edema and hyperemia
  - Erythema nodosum = septal panniculitis
- More common in shin regions and in children
- Many causes of panniculitis
  - Infection
    - Streptococcus, tuberculosis, rheumatic fever
  - Systemic inflammatory disorder
    - Polyarteritis nodosa, systemic lupus erythematosus, sarcoidosis, dermatomyositis, morphea, Takayasu arteritis, necrotizing vasculitis
  - Myeloproliferative disorder
    - Lymphoma, leukemia
  - Pancreatic disease
    - Pancreatitis (50%) or pancreatic carcinoma (50%)
    - May precede recognition of pancreatitis in 50%
  - Drug hypersensitivity
  - Weber-Christian disease: Rare inflammatory panniculitis
    - Fever, arthralgia, anemia, leucopenia, deranged liver function, subcutaneous panniculitis

Subcutaneous Fat Necrosis of Newborn
- Seen in otherwise normal newborns
- Single or multiple violaceous plaques or nodules usually on trunk
- Associated with preeclampsia, hypothermia, obstetric trauma, hypoxia, etc.
- Diffuse increased echogenicity of subcutaneous fat in affected areas ± calcification
- Histology shows lobular panniculitis with fat necrosis, granulomas, fibrosis, and calcification

PATHOLOGY

General Features
- Etiology
  - Following trauma
    - ~ 50% of patients report prior trauma
      - Trauma is likely cause even when patients cannot recall antecedent trauma
  - Following panniculitis

Gross Pathologic & Surgical Features
- Vary due to evolutionary nature of lesion
- Lobular thickening of subcutaneous fat surrounded by fibrous septa
- Later stages may show more dense fibrosis and atrophy of subcutaneous fat

Microscopic Features
- Incisional biopsy preferred over needle biopsy
  - No need to biopsy majority of cases
- Inflammatory infiltrate predominantly involving subcutaneous septa or lobules
  - Septal panniculitis ± vasculitis
  - Lobular panniculitis ± vasculitis
- Aggregates of foamy phagocytic macrophages
- Reactive fibrous tissue enveloping and separating areas of fat necrosis
  - May give rise to "bunch-of-grapes" appearance
- Cytology of cystic aspirate may reveal anuclear fat cells (vacuolated fat cells or "ghost cells")

CLINICAL ISSUES

Presentation
- Most common signs/symptoms
  - 50% recall trauma (days, weeks, or months)
  - Evolving lesion over weeks or months
  - Tender subcutaneous swelling
    - Progressing to induration and later atrophy
- Other signs/symptoms
  - Pain and tenderness in ~ 50%
  - May be asymptomatic and may present de novo as focal depression in subcutaneous tissues

Demographics
- Age
  - Young to middle age
- Gender
  - No sex predilection

Natural History & Prognosis
- Resolves over weeks or months with induration ± atrophy
- Indurated subcutaneous tissue either returns to normal, remains slightly indurated, or undergoes progressive fat atrophy leading to focal depression in skin surface

Treatment
- Often no specific treatment
- ± anti-inflammatory medication, if lesions are painful
- Percutaneous draining for Morel-Lavallée lesion
  - Surgical drainage and sclerodesis for chronic lesion

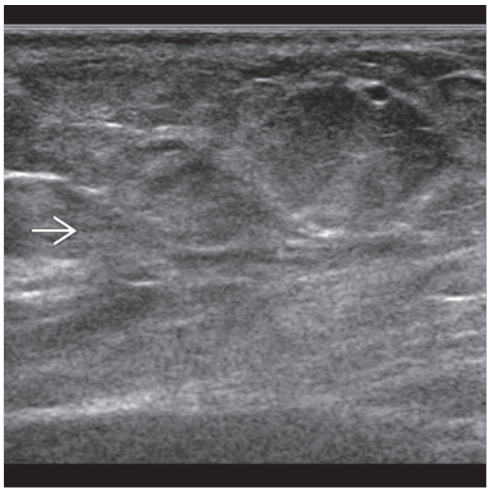
DIAGNOSTIC CHECKLIST

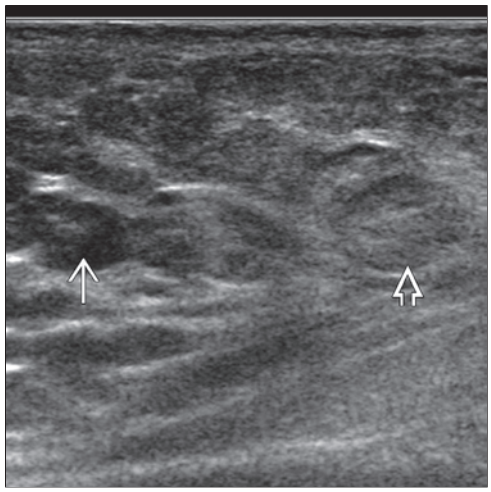
Consider
- Pancreatic disease in patient presenting with unexplained panniculitis or fat necrosis

Image Interpretation Pearls
- Ill-defined, localized echogenicity of subcutaneous fat clinically evolving over weeks or months is usually due to either panniculitis or fat injury

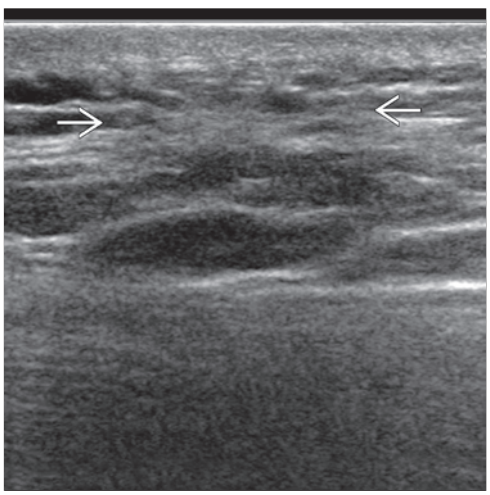
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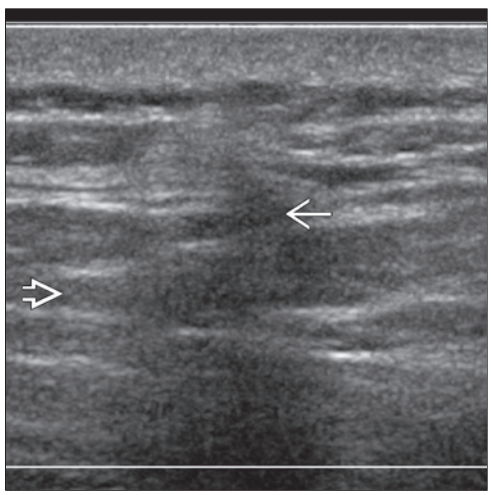
1. Walsh M et al: Sonography of fat necrosis involving the extremity and torso with magnetic resonance imaging and histologic correlation. J Ultrasound Med. 27(12):1751-7, 2008



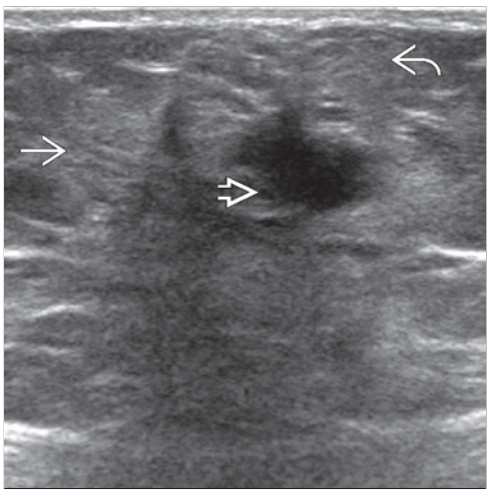


(Left) *Longitudinal ultrasound of the abdominal wall in a patient with a recent blunt injury to this area shows diffuse increase in subcutaneous echogenicity. The fat lobules are hyperechoic and poorly defined due to post-traumatic edema.* ***(Right)*** *Transverse ultrasound of the same lesion shows the difference in appearance between adjacent normal hypoechoic fat lobules and the edematous hyperechoic fat lobules of fat necrosis.*





(Left) *Longitudinal ultrasound of the buttock region shows an ill-defined area of increased echogenicity in the superficial subcutaneous fat. The normal striation of subcutaneous fat is obscured.* ***(Right)*** *Transverse ultrasound of the same lesion shows the presence of mild posterior shadowing due to fibrosis. Note how the deep subcutaneous fat layer is spared.*



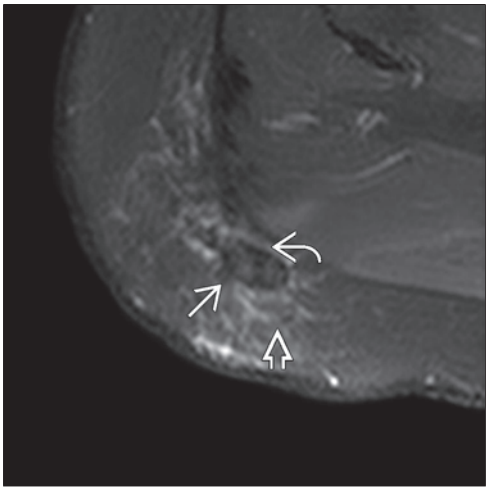


(Left) *Transverse ultrasound of a patient with a slowly enlarging post-traumatic mass in the abdominal wall shows a heterogeneous subcutaneous mass. The mass is composed of an ill-defined peripheral hyperechoic component and a discrete central hypoechoic component. Areas of subcutaneous fat necrosis become better defined and more hypoechoic with increasing chronicity.* ***(Right)*** *Axial T1WI MR of the same lesion shows a spiculated area of subcutaneous fat necrosis.*

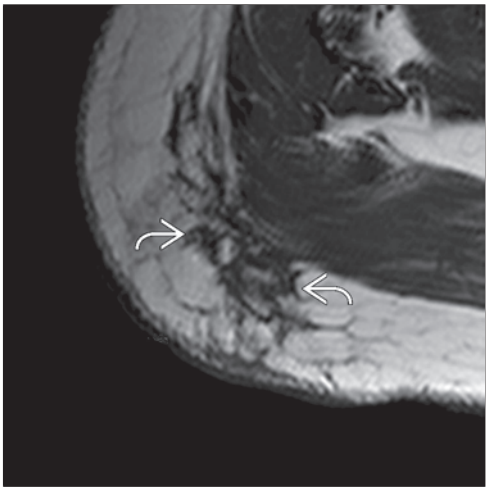
FAT INJURY

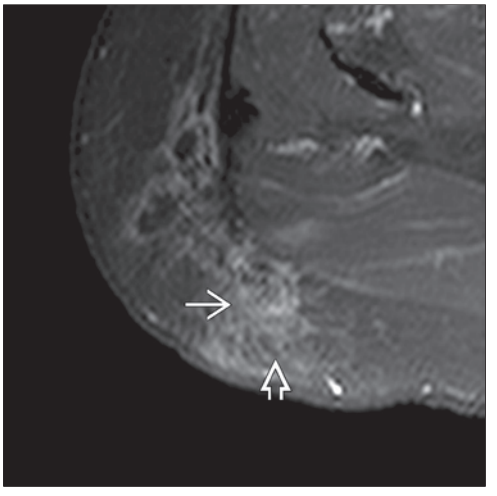
(Left) *Extended field-of-view ultrasound of a patient with a painful post-traumatic buttock nodule due to fat necrosis shows an irregular hypoechoic mass in the subcutaneous fat of the buttock. There is hypoechoic stranding extending into the surrounding fat with mild posterior acoustic shadowing.* ***(Right)*** *Axial T2WI FS MR of the same lesion shows a hypointense subcutaneous mass with a fibrotic hypointense pseudocapsule and mild perilesional edema.*



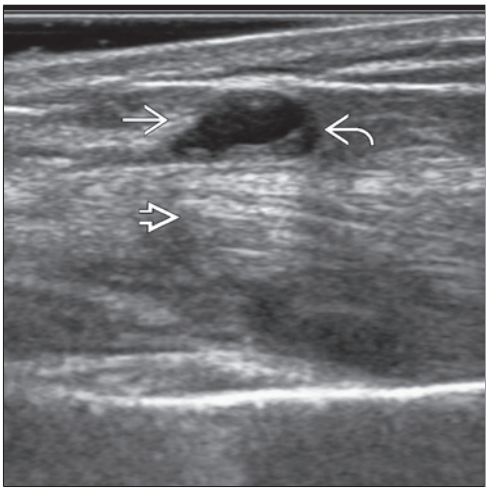


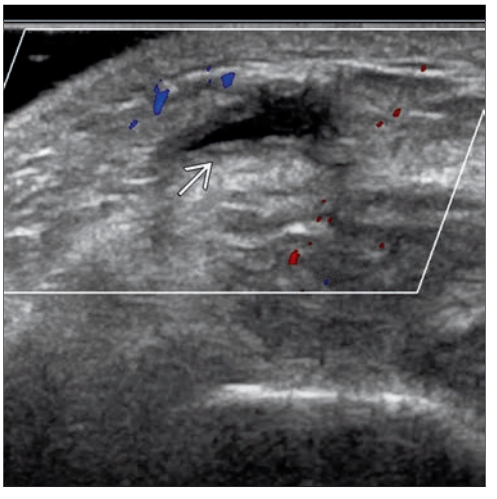
(Left) *Axial T1WI MR of the same lesion shows multiple strands of hypointense tissue extending into the surrounding subcutaneous fat.* ***(Right)*** *Axial T1WI C+ FS MR of the same lesion shows the presence of mild lesional and perilesional enhancement. This perilesional and lesional enhancement is consistent with inflammation and can account for the patient's pain. Low-grade inflammation is a feature of healing fat necrosis.*

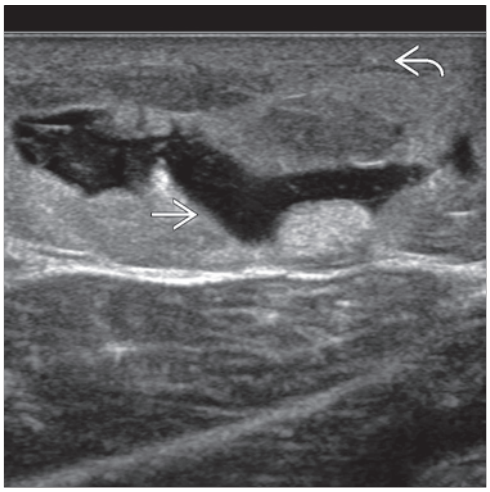


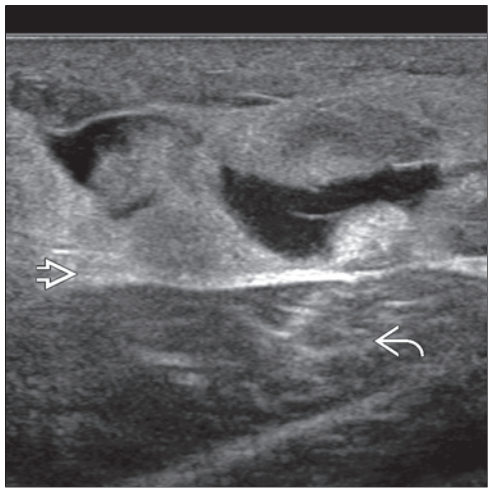


(Left) *Transverse ultrasound of the lateral thigh region shows a well-defined, cystic-type, subcutaneous mass with a pseudocapsule and mild posterior acoustic enhancement.* ***(Right)*** *Longitudinal color Doppler ultrasound of the same lesion shows no significant hyperemia around this area of cystic, post-traumatic fat necrosis. This is a mature lesion with no surrounding inflammation.*

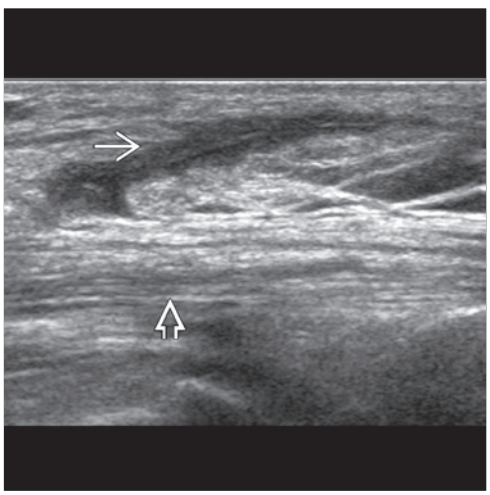


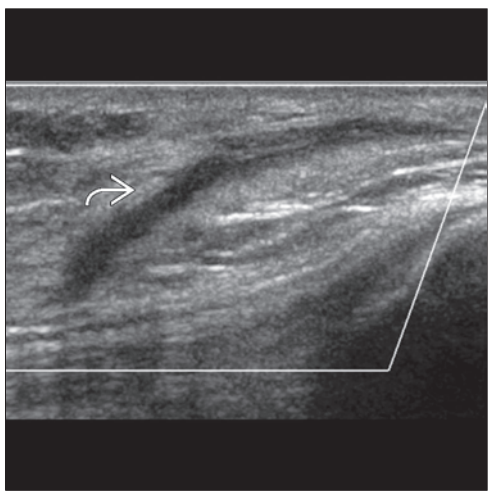




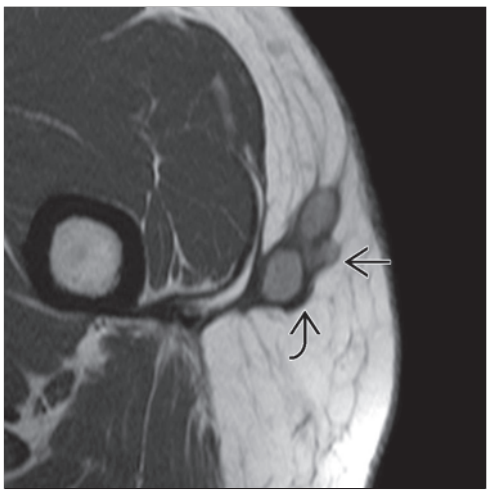


(Left) *Transverse ultrasound of a patient with recent history of crush injury to the calf shows an area of subcutaneous fat liquefaction secondary to subcutaneous fat necrosis. The subcutaneous fat is hyperechoic and swollen due to subcutaneous fat edema.* ***(Right)*** *Longitudinal ultrasound of the same lesion shows how the full depth of subcutaneous fat is affected. Mild edema is also present in the medial belly of the gastrocnemius just deep to the investing fascia.*





(Left) *Longitudinal ultrasound of a patient with subacute trauma to the knee shows a cleavage-type injury to the subcutaneous fat in the suprapatellar region. The quadriceps tendon is normal.* ***(Right)*** *Longitudinal color Doppler ultrasound of the same lesion shows no hyperemia. The linear hypoechoic cleavage space is filled with fluid. This cleavage injury is different to a Morel-Lavallée lesion where subcutaneous fat separates from the investing fascia.*



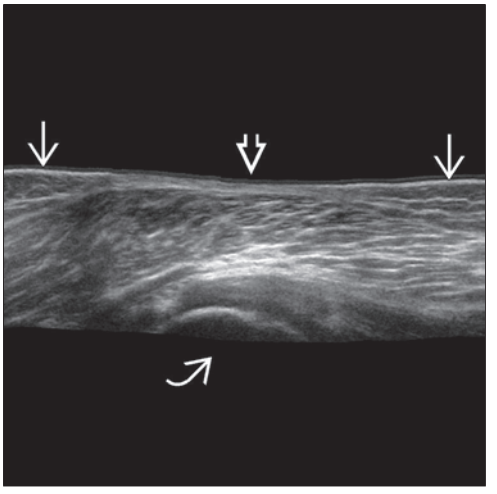


(Left) *Axial T1WI MR of a patient with a thigh mass that developed following trauma 2 years earlier shows a well-defined area of subcutaneous fat necrosis with intermediate signal in the lateral thigh region. There is a fibrotic pseudocapsule with strands of fibrosis extending into the adjacent subcutaneous fat.* ***(Right)*** *Coronal T1WI FSE MR of the same lesion shows the perilesional fibrotic strands extending superficially and distally close to the investing fascia.*

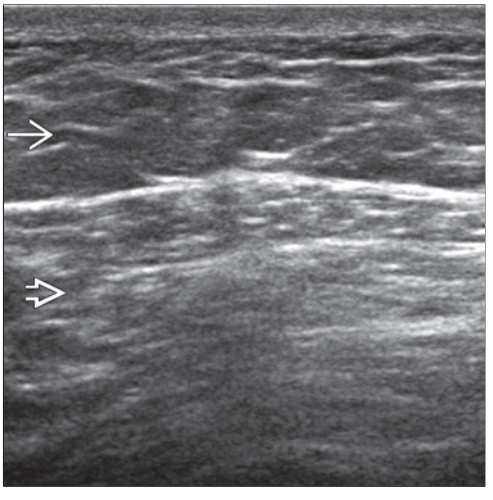
FAT INJURY

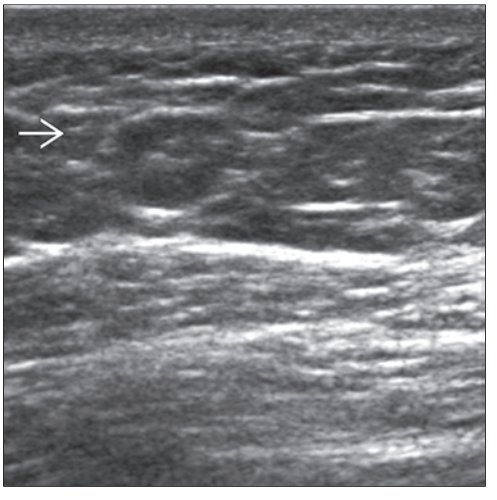
(Left) *Clinical photograph of a patient with previous history of buttock trauma shows severe focal contour depression in the buttock region.* ***(Right)*** *Extended field-of-view ultrasound in the same patient shows a focal area of severe subcutaneous fat atrophy. There is severe thinning of the subcutaneous fat compared to the adjacent normal subcutaneous fat. The underlying ischial tuberosity is normal.*



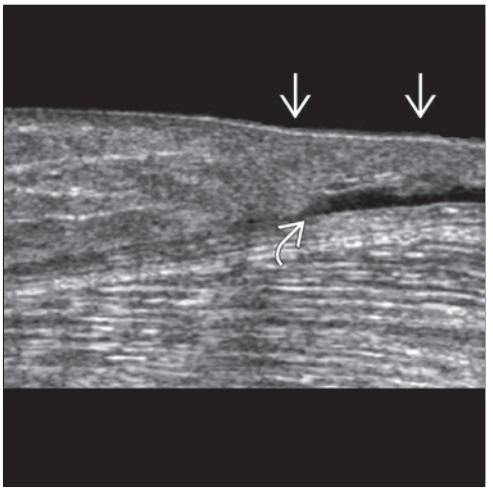


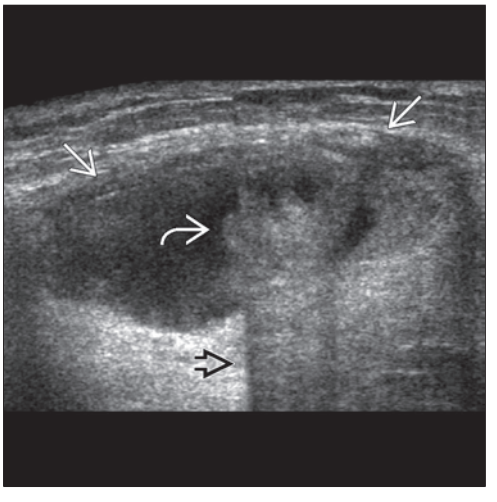
(Left) *Transverse ultrasound at edge of affected area in the same patient as previous image shows moderate thinning of the subcutaneous fat. The muscle layer is normal.* ***(Right)*** *Transverse ultrasound of the unaffected contralateral buttock in the same patient shows the normal thickness of the subcutaneous fat for comparison. One of the most frequent findings in fat necrosis is localized thinning of otherwise normal subcutaneous fat.*

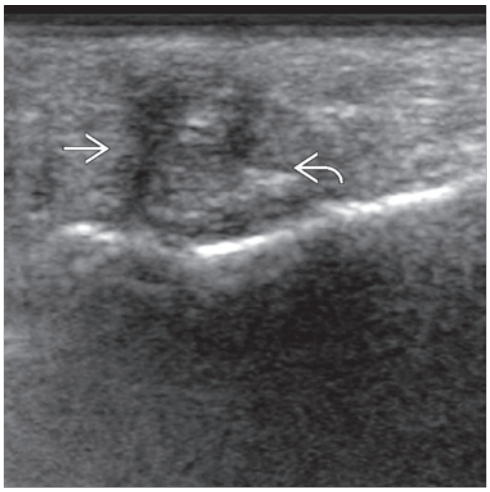


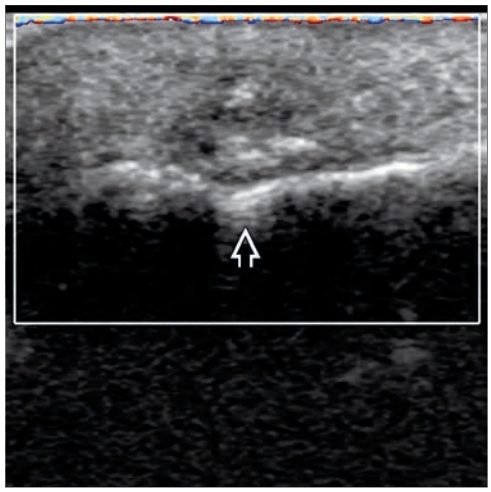


(Left) *Longitudinal ultrasound of the calf shows subcutaneous fat necrosis with loss of volume of subcutaneous fat and fluid accumulation adjacent to the investing fascia.* ***(Right)*** *Longitudinal ultrasound of the buttock region following trauma 2 months earlier shows a well-defined, largely cystic area of subcutaneous fat necrosis with early calcification accentuated by prominent acoustic shadowing.*

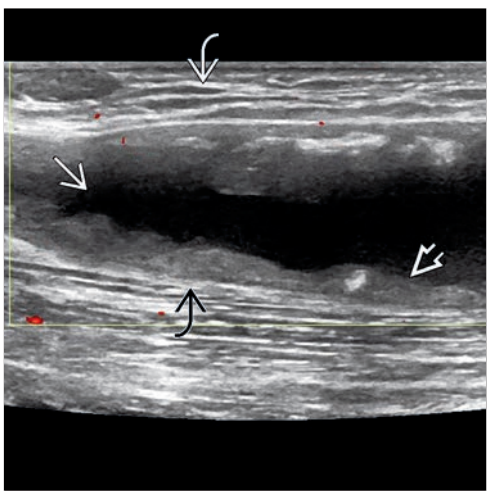


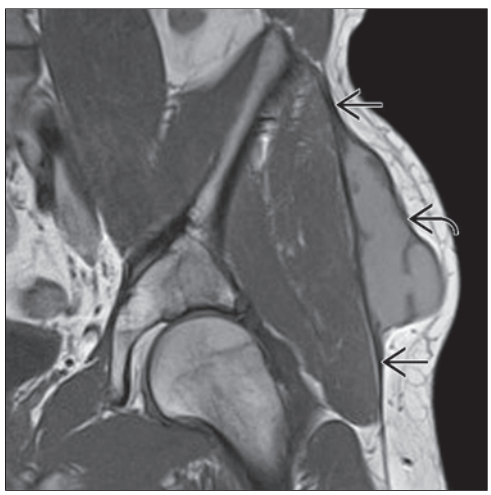






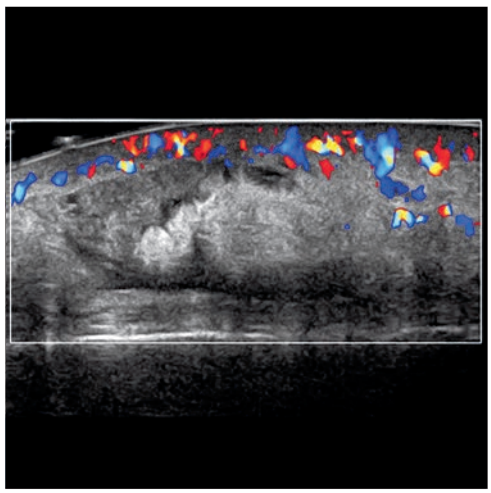
(Left) *Longitudinal ultrasound of the thumb of a patient with previous history of local injury shows a localized area of subcutaneous fat necrosis with early calcification. **(Right)** Longitudinal color Doppler ultrasound of the same lesion shows the absence of intrinsic vascularity. The proximal phalanx is normal. Post-traumatic fat necrosis tends to also occur in those areas with little or no muscle between skin and bone.*





(Left) *Longitudinal color Doppler US of the thigh several weeks after injury shows a Morel-Lavallée lesion with an elongated fluid collection lying between the investing fascia and the subcutaneous fat. The fluid collection has a thick irregular rim of hypoechoic traumatized fat. (Courtesy P. Robinson, MD.) **(Right)** Coronal T1WI MR of the pelvis shows an elongated fluid collection between the investing fascia and the subcutaneous fat of the pelvic sidewall consistent with a Morel-Lavallée lesion. (Courtesy P. Robinson MD.)*





(Left) *Longitudinal ultrasound of the shin region in a patient with prior history of trauma to this area who subsequently developed progressive erythema and swelling shows a large subcutaneous mass with marked surrounding edema. There are hypoechoic areas within the affected area, but no discrete liquefaction is present. **(Right)** Longitudinal color Doppler ultrasound of the same lesion shows moderate to severe hyperemia consistent with an infected area of subcutaneous fat necrosis.*

MUSCLE INFARCTION

Key Facts

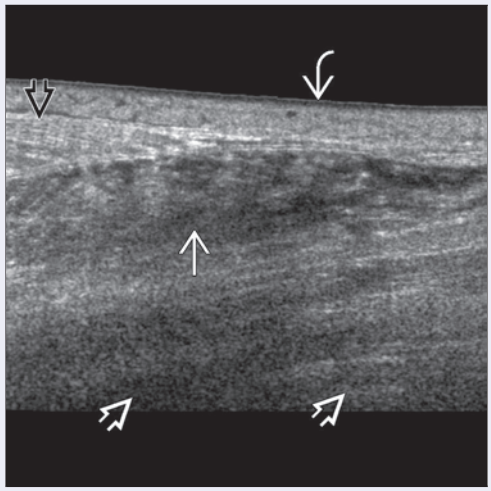
Imaging

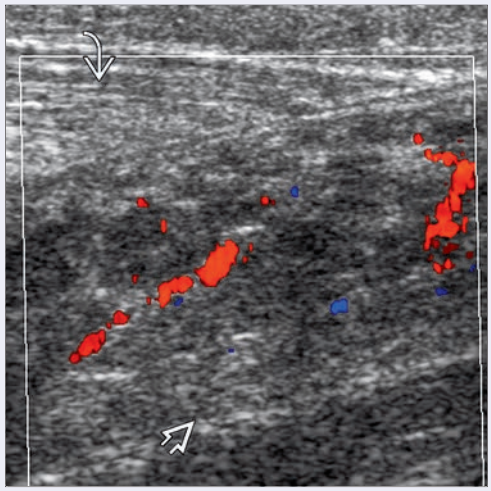
- Predilection for involvement of larger muscles in lower limb
  - Thigh (60%) > leg (40%)
  - Thigh: Anterior > posterior > medial compartment
  - Leg: Posterior > anterior = lateral compartment
  - Usually involves several muscles rather than a single muscle
  - Bilateral muscle involvement is uncommon (10%)
- Focal ill-defined swelling and hypoechogenicity of affected muscle
  - Effacement and disruption of affected muscular architecture
- ± subfascial fluid
- ± gas within infarcted area
- ± hemorrhage within infarcted area (best seen on MR)
- Subcutaneous tissue edema overlying infarcted area
- Mass-like area appears during reparative phase
  - Muscle echotexture is broadly recognizable within mass-like area
- Initially infarcted area is iso- or hypovascular relative to surrounding muscle
  - Becomes mildly hypervascular relative to surrounding muscle during reparative phase
- Biopsy for histological confirmation is usually not necessary

Clinical Issues

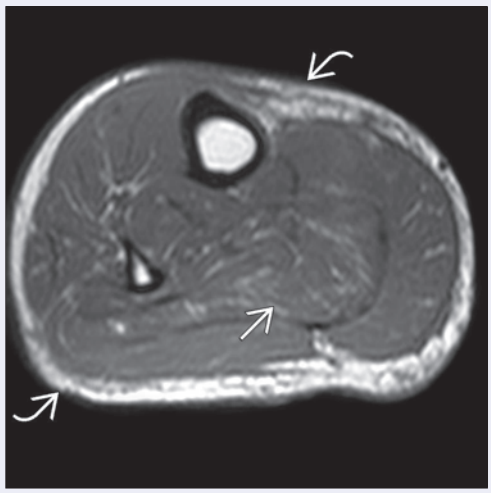
- Sudden onset of severe localized muscle pain with swelling of affected muscle
- Preexisting advanced diabetes
  - 20% of patients with muscle infarction die within 2 years due to other diabetic complications
- Settles in 5-8 weeks with conservative treatment
- Muscle infarction may also occur in patients with chronic renal failure or severe angiopathy though no diabetes

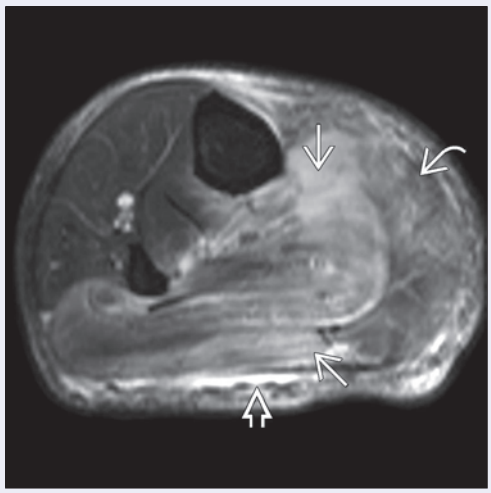
(Left) *Longitudinal ultrasound of a diabetic patient shows a swollen soleus muscle with a more hypoechoic area superficially, indicative of diabetic muscle infarction. There is mild subcutaneous edema. Note the relatively normal gastrocnemius muscle. **(Right)** Longitudinal color Doppler ultrasound in the same patient shows moderate hyperemia of the affected soleus muscle. The gastrocnemius muscle is not hyperemic.*





(Left) *Axial T1WI MR in the same patient shows mild diffuse subcutaneous edema with mild swelling of the soleus muscle. No muscle hemorrhage is present. **(Right)** Axial T2WI FS MR shows moderate to severe edema of the soleus muscle and lateral belly of gastrocnemius. The medial belly of the gastrocnemius muscle is only mildly edematous. Note mild subcutaneous edema with a small subfascial fluid collection. The appearances are compatible with diabetic muscle infarction.*





MUSCLE INFARCTION

TERMINOLOGY

Synonyms
- Diabetic muscle infarction, aseptic myonecrosis, ischemic myonecrosis, tumoriform focal muscular degeneration

Definitions
- Muscle infarction leading to muscle cell death

IMAGING

General Features
- Best diagnostic clue
  - Focal muscle edema in susceptible diabetic patient
- Location
  - Deep within affected muscle
  - Usually involves several muscles rather than a single muscle
  - Predilection for involvement of larger muscles in lower limb
  - Thigh (60%) > leg (40%)
    - Thigh: Anterior compartment (100%), posterior compartment (65%), medial compartment (55%)
    - Leg: Posterior compartment (90%), anterior compartment (20%), lateral compartment (20%)
  - Gluteal muscle is not uncommonly affected
  - Upper limb & abdominal muscle are uncommonly affected
  - Bilateral muscle involvement is uncommon (10%)
- Size
  - Variable, though typically 3-5 cm
- Morphology
  - Initially, affected muscle is swollen
  - Later, firm muscle mass may develop at affected site

Radiographic Findings
- Radiography
  - Arterial calcification is indicative of diabetic vasculopathy

MR Findings
- T1WI
  - Swollen isointense affected muscle
  - ± focal hyperintensity within affected muscle due to hemorrhage (40%)
    - Hemorrhage within affected area is better seen on MR than US
- T2WI FS
  - Focally edematous muscle
    - Degree of muscle edema is more pronounced on MR than on ultrasound
    - ± discrete mass at site of infarction
    - ± subfascial fluid collection (60-100%)
      - More common in thigh than in leg
  - Subcutaneous edema (100%)
- T1WI C+
  - Generally not advocated due to risk of nephrogenic systemic fibrosis
  - Diffuse or rim-enhancement pattern
    - Not beneficial in predicting outcome
  - Most diagnostic information is available from noncontrast examination

Ultrasonographic Findings
- Grayscale ultrasound
  - Focal ill-defined swelling & hypoechogenicity of affected muscle
  - Effacement & disruption of affected muscular architecture
  - ± fluid superficial to infarcted muscle area (subfascial fluid)
    - Can be gravity dependent so less readily appreciated on US than on MR
  - ± gas within infarcted area, seen as echogenic foci with reverberation artifact
  - Subcutaneous tissue edema overlying infarcted area
    - Varies according to extent, severity, & duration of infarction
    - Degree of subcutaneous edema may provide clue to duration of infarction
  - Infarcted area may resolve or evolve into medium-sized discrete, well-marginated, hypoechoic mass
    - Mass appears during reparative phase & is not a feature of acute phase
    - Echotexture of muscle is broadly preserved within mass-like area
    - Mass slowly resolves, tending to become better defined & firmer with time
  - Calcification is not a feature
  - Ultrasound can exclude deep venous thrombosis more readily than MR or CT
- Color Doppler
  - Initially, affected area is iso- or hypovascular relative to surrounding muscle
    - Later becomes mildly hypervascular compared with surrounding muscle

Imaging Recommendations
- Best imaging tool
  - Ultrasound to help confirm diagnosis of diabetic muscle infarction & exclude likely differential diagnoses
- Protocol advice
  - Perform early examination followed by serial examinations at intervals of 3-4 weeks for 9-12 weeks to observe changing nature of lesion
  - Routinely compare vascularity of affected muscle with contralateral unaffected muscle
  - Biopsy for histological confirmation is usually not necessary
    - Biopsy is indicated only for atypical presentation, equivocal findings, or not settling as expected to treatment
    - Aspiration of fluid for culture may be helpful if secondary secondary infection is suspected

DIFFERENTIAL DIAGNOSIS

Muscle Abscess
- Severe pain & tenderness ± fever
- Predominant fluid component
- Deteriorates & becomes more liquefied with time
- Purulent fluid on aspiration

Pyomyositis
- Severe pain & tenderness ± fever
- Diffuse muscle edema & hyperemia

MUSCLE INFARCTION

- ± discrete fluid collection

Deep Venous Thrombosis
- Noncompressibility of affected vein
- Visible thrombus within veins
- Poor phasicity on spectral analysis

PATHOLOGY

General Features
- Etiology
  - Probably caused by microvascular occlusion due to arteriosclerosis obliterans, thrombus, or embolus
  - Hypoxia: Reperfusion injury & hypercoagulable state may also be contributory
- Associated abnormalities
  - Longstanding insulin-dependent diabetes
  - Poor control of glycemia
  - Presence of microvascular diabetic complications (neuropathy, retinopathy, nephropathy)

Gross Pathologic & Surgical Features
- Swollen, nonhemorrhagic, pale-looking muscle

Microscopic Features
- Muscle necrosis (myonecrosis) & edema
  - Phagocytosis of necrotic muscle fibers
- Acute or chronic inflammatory infiltrate
  - Greater if secondary infection
- Granulation tissue repair with fibrosis
- Small arteries of infarcted area may have thickened hyalinized walls & be occluded with fibrin clot or calcium fragments

CLINICAL ISSUES

Presentation
- Most common signs/symptoms
  - Sudden onset of severe localized muscle pain with swelling of affected muscle
  - Preexisting advanced diabetes
- Other signs/symptoms
  - Often delay between onset of symptoms & presentation (average 4 weeks)
  - Resolution of swelling with appearance of painful palpable mass (33%) over 3 weeks
  - Fever (10%)
  - Secondary infection of affected muscle area is not uncommon
- Clinical profile
  - Mean duration of diabetes prior to diabetic muscle infarction is 15 years
    - Insulin-dependent diabetics (30%), noninsulin-dependent diabetics (30%), noninsulin-dependent diabetics on insulin regime (30%)
  - Accompanying diabetic complications are common
    - Nephropathy (70%)
    - Retinopathy (60%)
    - Neuropathy (60%)
    - Peripheral vascular disease (10%)
    - Hypertension (10%)
  - Laboratory tests are inconclusive
    - Elevated creatine kinase (50%)
      - Particularly if obtained soon after onset of symptoms
      - Will normalize in about a week
    - Elevated white cell count (10%)
    - Elevated C-reactive protein (50%)
    - Elevated erythrocyte sedimentation rate (50%)
  - Muscle infarction may also occur in patients with chronic renal failure or severe angiopathy though no diabetes

Demographics
- Age
  - Range: 19-81 years (mean: 42 years)
    - Insulin-dependent diabetics are affected at younger age than noninsulin-dependent diabetics
- Gender
  - Slightly more common in diabetic women (60%)
- Epidemiology
  - Diabetes mellitus affects 5% of population
  - Muscle infarction is an uncommon complication of diabetes

Natural History & Prognosis
- Settles in about 5-8 weeks with conservative treatment
- ~ 1/3 of patients have 2nd episode of muscle infarction
  - Most commonly involves different muscle (85%) rather than same muscle (15%)
- Diabetic muscle infarction is a poor prognostic sign
  - 20% of patients die within 2 years due to other diabetic complications

Treatment
- Conservative
  - Bed rest & non-weight-bearing
    - Leg elevation
  - Analgesia & symptomatic treatment
  - Gradual resumption of activity as pain resolves
  - Careful metabolic control of diabetes (may reduce likelihood of recurrence)
  - Usually resolves spontaneously
    - Nonsteroidal anti-inflammatory agents
    - Antiplatelet therapy if hypercoagulable state
    - Steroids if antiphospholipid antibodies are present
- Complications
  - Biopsy may induce bleeding into infarcted area
  - Secondary infection of infarcted muscle (uncommon)

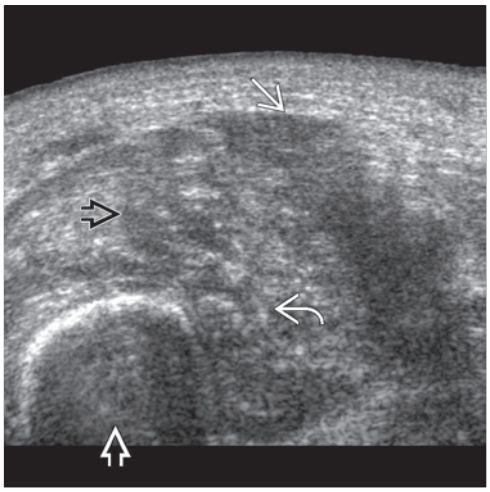
DIAGNOSTIC CHECKLIST

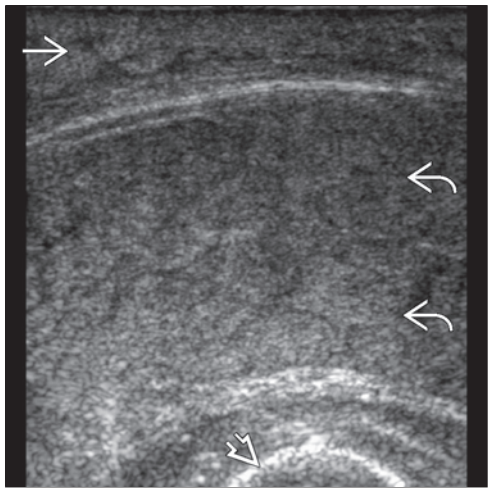
Consider
- Diabetic muscle infarction in any patient with known diabetic complication presenting with muscle pain

Image Interpretation Pearls
- Diagnosis is based on recognition of typical ultrasound findings in at-risk patient
- Serial examination showing evolving ultrasound changes will allow definitive diagnosis without need for percutaneous biopsy

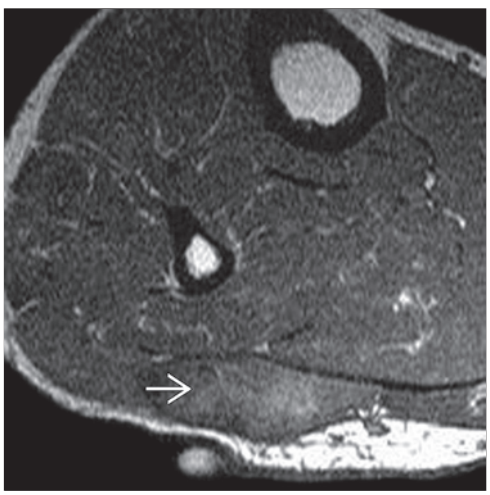
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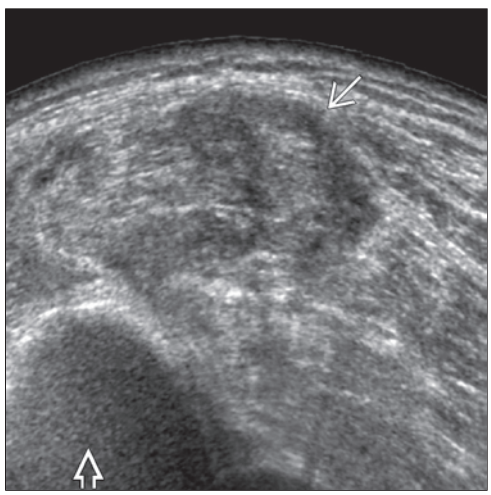
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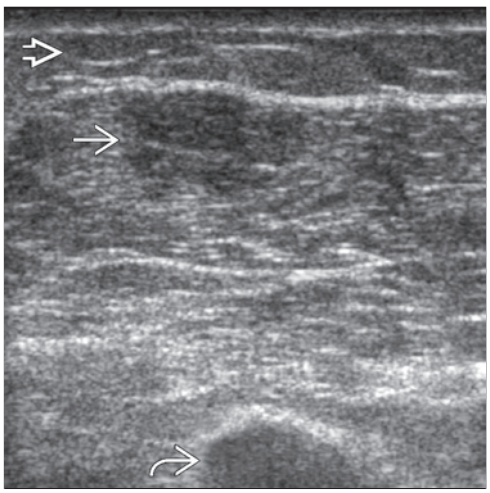


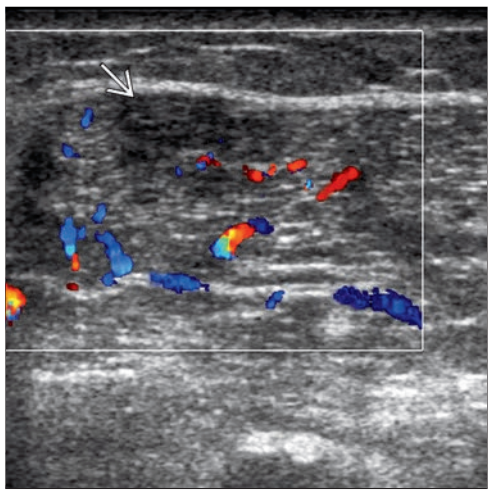
(Left) *Transverse ultrasound in a diabetic patient shows a well-defined swollen hypoechoic area of vastus lateralis muscle infarction. The small echogenic foci are possibly due to gas. There is a more hypoechoic edematous area laterally. The femoral shaft is normal.* ***(Right)*** *Transverse ultrasound in a diabetic patient shows a diffusely swollen vastus intermedius muscle with subcutaneous edema, consistent with recent muscle infarction. The femoral shaft is shown.*





(Left) *Transverse T1WI MR in a diabetic patient shows an ill-defined area of hyperintensity within the mildly swollen lateral belly of the gastrocnemius muscle due to hemorrhage within an area of muscle infarction.* ***(Right)*** *Transverse ultrasound in a diabetic patient shows a well-defined hypoechoic area due to peroneal muscle infarction. The muscle architecture can still be appreciated within the infracted area, i.e., no discrete muscle mass is present. The proximal fibula is normal.*





(Left) *Transverse ultrasound in a diabetic patient shows a well-defined hypoechoic area with broadly preserved background muscle architecture due to resolving biceps brachii muscle infarction. There is no subcutaneous edema. The humeral shaft is normal.* ***(Right)*** *Transverse color Doppler ultrasound at the same location (same patient) shows moderate hyperemia around the infarcted hypoechoic area. In a typical patient, these appearances require no additional imaging.*

MUSCLE INJURY

Key Facts

Terminology

- Tear: Stretch injury of muscle with tear of muscle or myofascial fibers
- Contusion: Direct blunt compressive trauma to muscle without definable tear
- Hernia: Abnormal protrusion of part of muscle out of investing fascia in which it is normally contained

Imaging

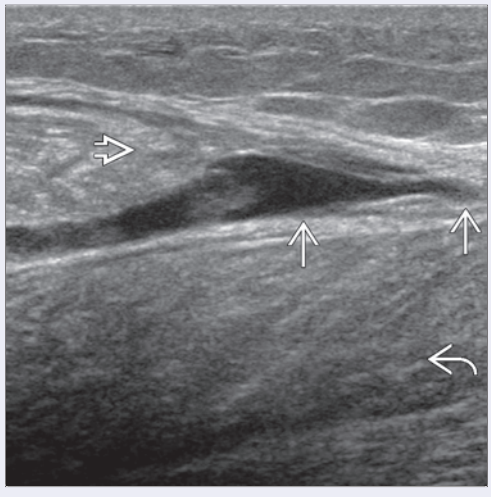
- **Muscle or myofascial tear**
  - Discontinuity ± retraction of muscle fibers either within muscle or at myofascial junction
  - Tear filled with hematoma or fluid
  - ± mild muscle and subcutaneous edema
- **Muscle contusion**
  - Ill-defined hyperechogenicity of muscle, which may cross fascial boundary
  - No discrete muscle tear (fiber discontinuity)
- **Muscle hematoma**
  - Typically associated with grade II or III tears
  - Appearance varies with duration of hematoma, severity, and location
- **Delayed onset muscle soreness (DOMS)**
  - Affected muscle may be normal or, if severe, diffusely hyperechoic due to diffuse muscle edema
- **Muscle hernia**
  - Focal protrusion of muscle fibers through investing fascia
  - Accentuated by muscle contraction or standing

Clinical Issues

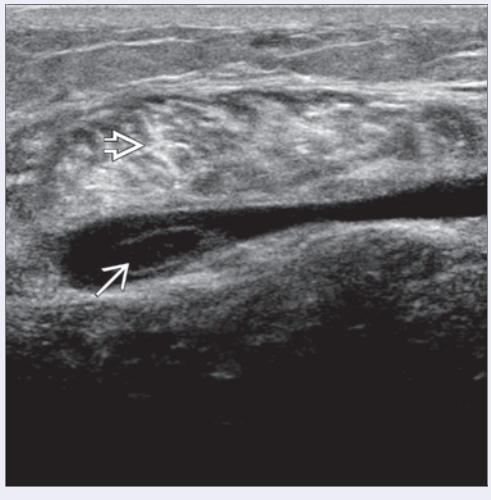
- Most muscle injuries improve with conservative treatment
  - Serial ultrasound examination not useful for guiding speed of rehabilitation
  - Speed of rehabilitation should be gauged clinically

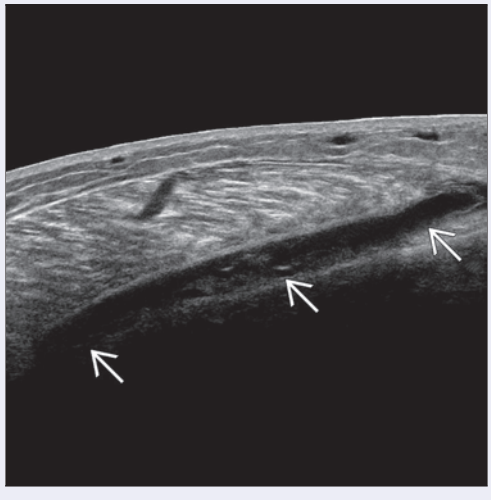
(Left) *Clinical photograph shows a patient with a recent calf muscle tear. There is moderate calf swelling and bruising with more intense bruising at the ankle region. **(Right)** Longitudinal ultrasound in the same patient shows a typical myofascial tear of the calf muscle ("tennis leg") with stripping of the medial head of the gastrocnemius at the myofascial junction with the soleus muscle. The retraction gap is filled with blood. There is moderate generalized soft issue edema.*





(Left) *Transverse ultrasound at the distal end of the medial head of the gastrocnemius muscle in the same patient shows liquefied blood filling the gap created by the retracted gastrocnemius muscle. This broad-based gastrocnemius muscle stripping is not seen in a plantaris tendon tear. **(Right)** Extended field-of-view ultrasound of the same area shows gastrocnemius muscle stripping extending along the entire soleus myofascial junction, indicative of a large gastrocnemius muscle tear.*





MUSCLE INJURY

TERMINOLOGY

Synonyms
- Pulled muscle, muscle strain, tennis leg, plantaris tear, muscle contusion, muscle hematoma, delayed onset muscle soreness (DOMS), muscle hernia

Definitions
- Tear: Stretch injury of muscle with tear of muscle or myofascial fibers
- Contusion: Direct blunt compressive trauma to muscle without definable tear
- Hernia: Abnormal protrusion of part of muscle out of investing fascia in which it is normally contained

IMAGING

General Features
- Best diagnostic clue
  - Muscle tear; hypoechoic area within muscle or at myofascial junction
- Location
  - Usually affects lower limb muscles (gastrocnemius > soleus > rectus femoris)
    - Myofascial junction injury is more common than intramuscular
- Morphology
  - Muscle fiber discontinuity with local hemorrhage and edema

Radiographic Findings
- Radiography
  - Usually normal

MR Findings
- T1WI
  - Muscle tears
    - Low to intermediate signal intensity hemorrhage
    - ± hyperintense subacute hemorrhage
    - Peripheral hypointense hemosiderin
    - Loss of normal muscle striations ± retracted muscle belly
  - DOMS
    - Muscle swelling of intermediate signal intensity
  - Muscle hernia
    - Focal defect in investing fascia ± muscle protrusion
    - Often accompanying vessel
- T2WI
  - Muscle tear
    - Hyperintense edema in affected muscle
    - Inhomogeneous signal intensity mass in midsubstance tears due to hemorrhage and edema
    - Perimuscular hyperintense fluid
  - DOMS
    - Diffuse homogeneous hyperintensity
- T2* GRE
  - Susceptibility artifact due to hemorrhage

Ultrasonographic Findings
- **Muscle or myofascial tear**
  - Discontinuity ± retraction of muscle fibers either within muscle or at myofascial junction
  - Tear filled with hematoma or fluid
  - ± mild to moderate muscle and subcutaneous edema
  - Gastrocnemius muscle tear
    - Especially common at distal end of medial head of gastrocnemius
    - Blunting of normal arrowhead configuration
    - Hematoma extending along gastrocnemius:soleus myofascial plane
    - In patients presenting with "tennis leg"
      - ~ 65% will have tear a distal gastrocnemius myofascial junction
      - ~ 20% will have a gastrocnemius:soleus myofascial tear not centered at distal myofascial junction
      - ~ 3% will have plantaris tendon tear
      - ~ 2% will have soleus muscle tear
      - ~ 10% will have other pathology (ruptured Baker cyst, Achilles tendon tear, deep venous thrombosis)
- **Muscle contusion**
  - Ill-defined hyperechogenicity of muscle, which may cross fascial boundary
  - No discrete muscle tear (fiber discontinuity)
  - Hyperemia during reparative phase
- **Muscle hematoma**
  - Typically associated with grade II or III tears
  - Appearance varies with duration, severity, and location of hematoma
  - Hypoechoic, usually well-defined mass ± hyperechoic hematoma
  - ± acoustic enhancement
  - Liquefaction seen as anechoic areas, usually more centrally than at rim of hematoma
  - Marginal hyperemia during reparative phase (reparative fibrovascular granulation tissue)
    - Peripheral granulation tissue usually hyperechoic and hyperemic
    - Granulation tissue is more hyperechoic than fresh hematoma
- **DOMS**
  - Affected muscle may be normal or, if severe, diffusely hyperechoic due to diffuse muscle edema
- **Muscle hernia**
  - Focal protrusion of muscle fibers through investing fascia
  - Accentuated by muscle contraction or standing

Imaging Recommendations
- Best imaging tool
  - Ultrasound since most muscle tears are accessible to ultrasound examination
- Protocol advice
  - Examine with muscle at rest and compare with contralateral side
  - Examine all tears in 2 planes
  - Measure dimensions of tear & try to gauge what % of muscle or muscle myofascial junction is torn
  - Gastrocnemius muscle tear: Look closely at distal myofascial junction comparing with opposite side
    - Check for integrity of plantaris tendon
  - Muscle hernia: Reexamine after exercise if hernia is not apparent on initial examination

DIFFERENTIAL DIAGNOSIS

Tendon Tear
- Quadriceps

MUSCLE INJURY

- Patella
- Achilles

Soft Tissue Tumor
- May mimic muscle tear with palpable mass
- Healing muscle tears have recognizable background muscle architecture and less mass effect
- Peripheral hyperemia of healing tear as opposed to central hyperemia of tumor

Deep Venous Thrombosis
- Noncompressibility of affected vein, lack of distal augmentation
- Thrombus visible within vein

PATHOLOGY

General Features
- Etiology
  - Muscle tear and hematoma
    - Strenuous athletic activity
    - Inadequate stretching and warm-up exercises (possibly)
    - Violent eccentric contraction
  - DOMS: Reversible structural damage at cellular level due to unaccustomed severe repetitive exertion
- Relevant anatomy
  - Plantaris muscle and tendon originate medial to lateral head of gastrocnemius and inserts anteromedial to Achilles tendon
  - In midcalf, plantaris tendon is located deep to medial head of gastrocnemius muscle
  - Seen as small ovoid structure within myofascia deep to medial head gastrocnemius
  - Near insertion is barely distinguishable from Achilles tendon
  - Plantaris is absent in 10% legs (2/3 absent bilaterally)

Staging, Grading, & Classification
- Grade 1: Small tear involving a few muscle fibers or myofascial unit (< 5%)
- Grade 2: Partial (5% to < 100%) tear of muscle or myofascial unit
- Grade 3: Complete (100%) tear of muscle or myofascial unit and retraction

Gross Pathologic & Surgical Features
- Musculotendinous junction tear
- Intrasubstance muscle tear
- Tear at deep intramuscular musculotendinous junction

Microscopic Features
- Muscle edema, hemorrhage, and phagocytosis
- Muscle fiber necrosis, edema with macrophagic infiltrate
- Fibroblastic response

CLINICAL ISSUES

Presentation
- Most common signs/symptoms
  - Tear and hematoma: Sudden onset of limb pain at time of exertion; "pop" sensation
    - Localized swelling and tenderness ± discrete mass
    - Complete rupture: Palpable defect with retracted mass
  - DOMS: Swelling and pain beginning 1-2 days after exercise, peaking at 3 days and resolving by day 7
  - Muscle hernia: Chronic pinpoint pain and tenderness
    - Usually has well-developed musculature

Demographics
- Age
  - Young to middle-aged athlete
    - In children, apophyseal avulsion fractures tend to predominate
    - In older patients, tendon tears predominate
- Epidemiology
  - Muscle injury: 30% of sports-related injuries
  - Rectus femoris: Most frequently injured quadriceps muscle
  - Medial head gastrocnemius myofascial tear is much more common than plantaris tendon tear

Natural History & Prognosis
- Most muscle injuries improve with conservative treatment
  - Serial ultrasound examination is not useful for guiding speed of rehabilitation
  - Speed of rehabilitation should be gauged clinically
- Surgery is indicated for compartment syndrome, complete tear, and muscle hernia
  - Compartment syndrome occurs with severe tears

Treatment
- Conservative
  - Rest, ice, compression, elevation (RICE)
  - Physical therapy: Stretching and exercises
  - Non-steroidal anti-inflammatory drugs (NSAIDs)
  - Gradual increase in activity
- Surgery
  - Decompression for compartment syndrome
  - Hematoma evacuation
  - Suturing of complete muscle rupture
  - Repair of investing fascia defect (if muscle hernia)
  - Resection of fibrotic mass

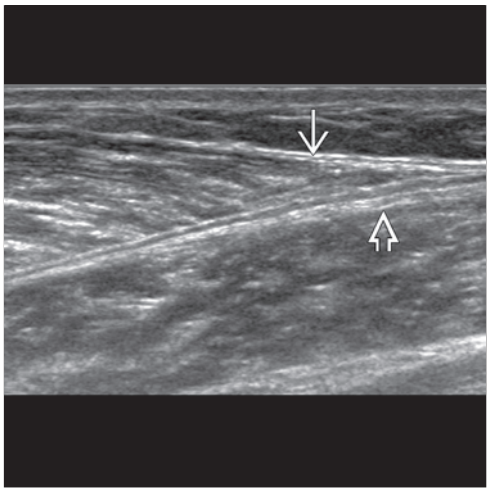
DIAGNOSTIC CHECKLIST

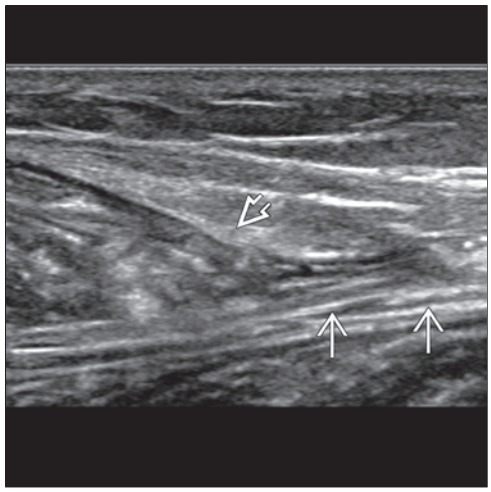
Consider
- Muscle hernia in any muscular patient with pinpoint muscle pain and tenderness

Image Interpretation Pearls
- Pay particular attention to distal myofascial junction of medial head gastrocnemius for small tears

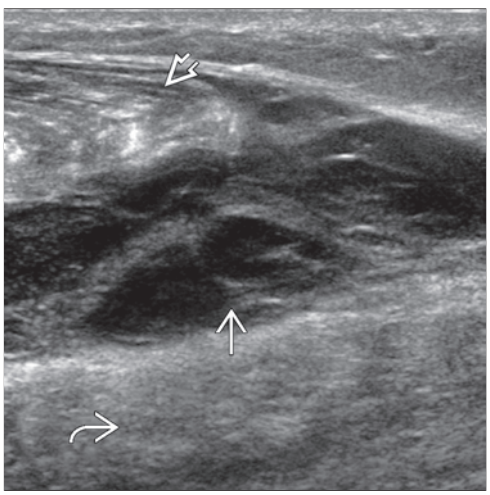
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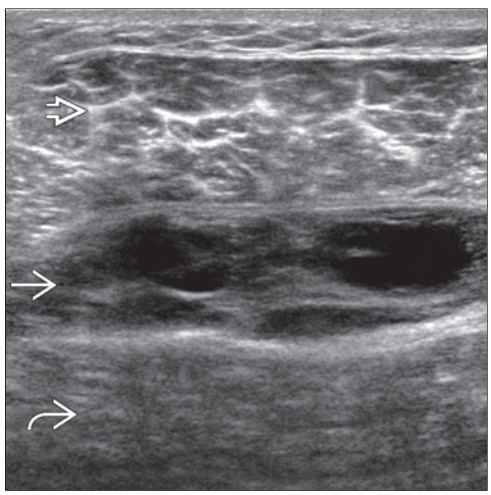
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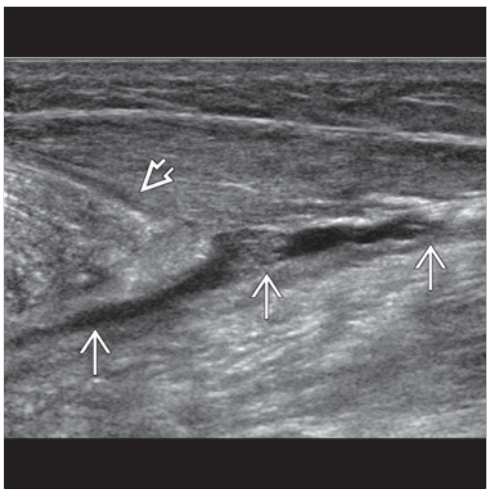


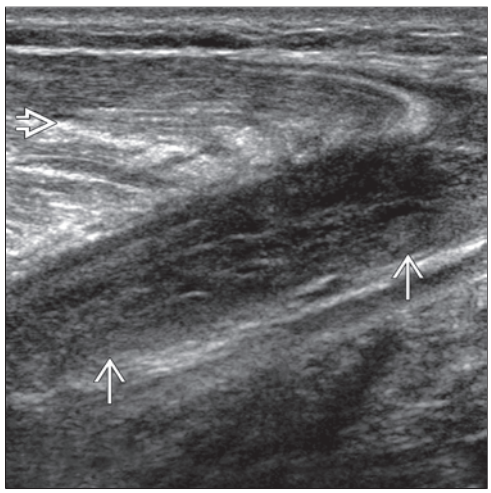
(Left) *Longitudinal ultrasound shows a normal, sharp arrowhead configuration of the medial head of the gastrocnemius muscle* ➔ *at the distal myofascial junction with soleus muscle* ➔. *This area requires very careful examination in a suspected calf muscle tear.* ***(Right)*** *Longitudinal ultrasound in a patient with a mild medial gastrocnemius muscle tear shows blunting of a normal arrowhead configuration* ➔, *mild stripping of muscle from soleal myofascial junction* ➔, *and moderate soft tissue edema.*





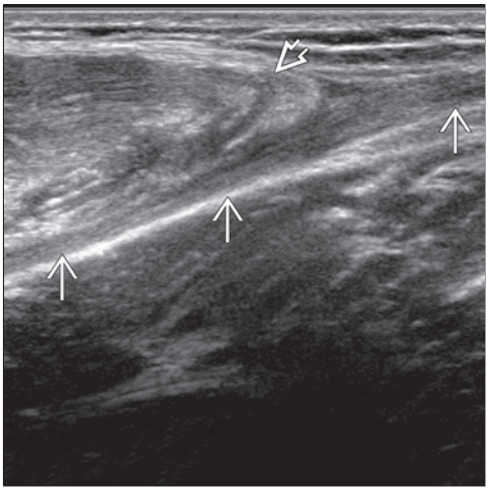
(Left) *Longitudinal ultrasound shows a severe acute medial head of gastrocnemius tear with a large, partially liquefied hematoma* ➔ *filling the gap created by retraction of the medial head of the gastrocnemius muscle* ➔ *from the myofascial junction with the soleus muscle* ➔. ***(Right)*** *Transverse ultrasound shows a hematoma* ➔ *filling the gap between the medial head of the gastrocnemius muscle* ➔ *and the soleus muscle* ➔. *Even large myofascial calf hematomas will resolve without sequelae over 8-12 weeks.*

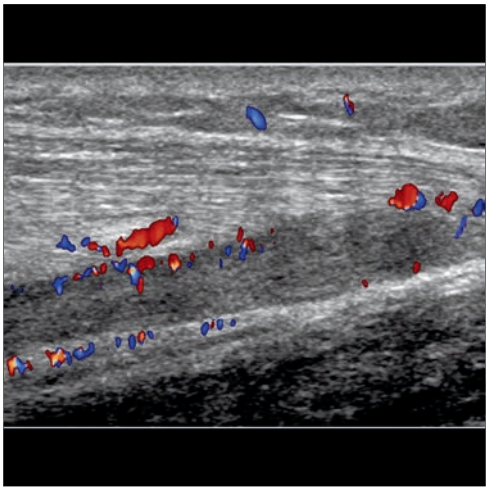




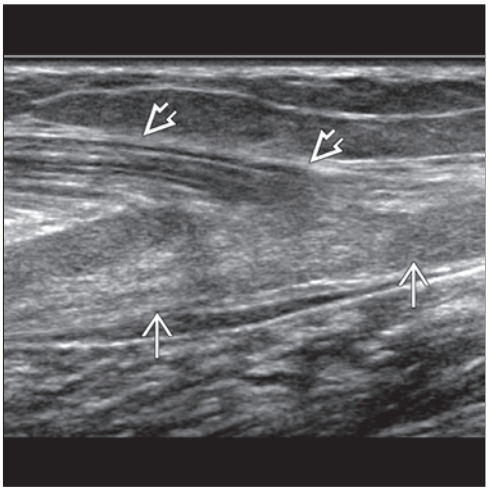
(Left) *Longitudinal ultrasound shows retraction of the medial head gastrocnemius* ➔ *with a medium-sized myofascial tear* ➔. *Minimal hematoma is present. The length and breadth of each tear should be reported as well the amount of muscle retraction and degree of hematoma (if present).* ***(Right)*** *Longitudinal ultrasound shows a large medial gastrocnemius* ➔ *myofascial tear with moderate-sized hematoma* ➔ *filling the site of tear. Hematoma tends to be more hypoechoic than reparative granulation tissue.*

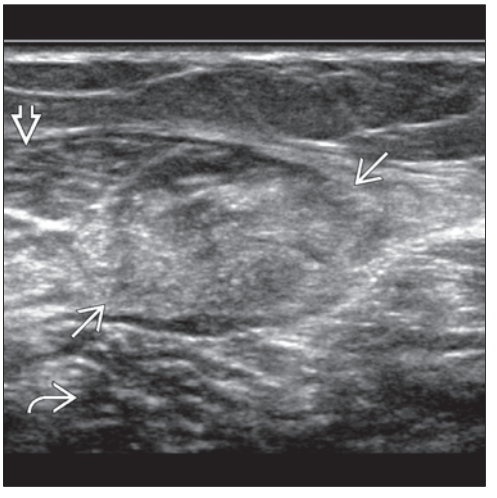
(Left) *Longitudinal ultrasound 2 months following a calf muscle tear shows a retracted medial head of the gastrocnemius with reparative granulation tissue filling the retraction gap. Reparative tissue is generally more hyperechoic than hematoma.* ***(Right)*** *Longitudinal color Doppler ultrasound at same location shows moderate marginal hyperemia of this granulation tissue. This appearance can remain for many months following calf muscle repair even though clinical symptoms have resolved.*



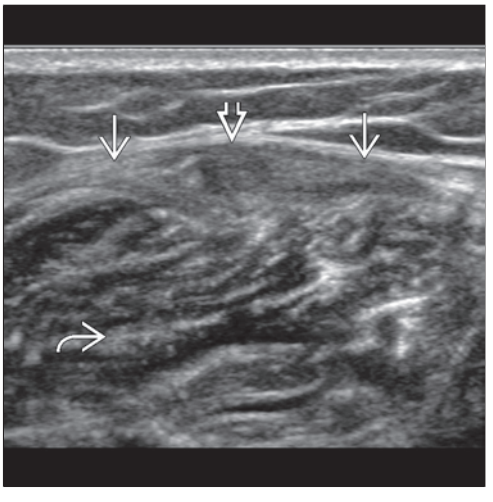


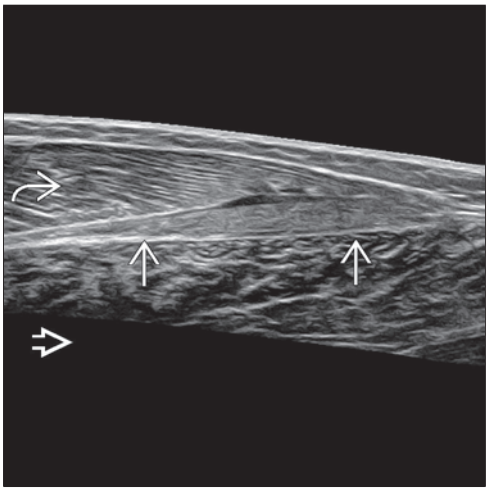
(Left) *Longitudinal ultrasound shows a retracted medial head of the gastrocnemius with quite marked calf muscle reparative fibrosis 3 months following the calf muscle tear.* ***(Right)*** *Transverse ultrasound at the same location shows a mass-like nodular fibrosis due to a healing calf muscle tear. Such a tear may take 1-2 years to fully resolve. The medial head of the gastrocnemius muscle and the soleus muscle are shown.*

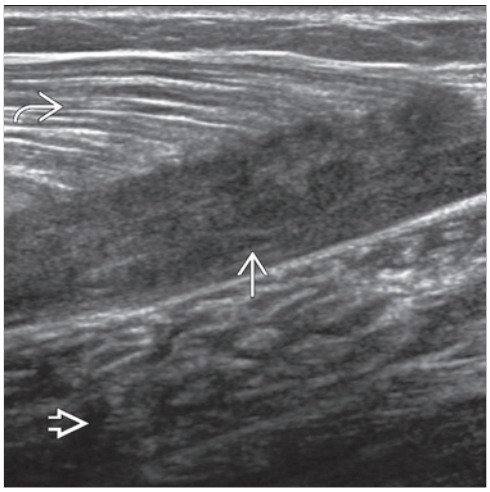


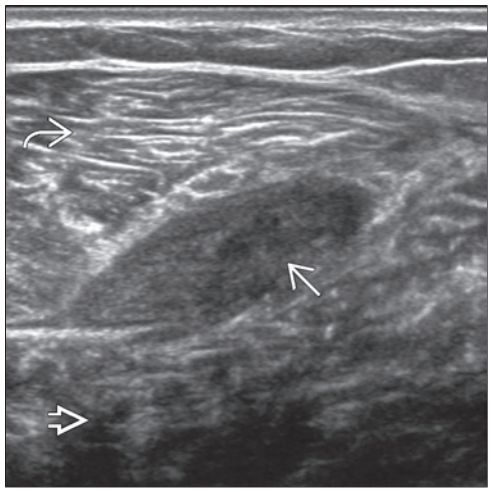


(Left) *Transverse ultrasound in a middle-aged man with an acute snapping sensation in the calf while running shows a moderate hematoma around a swollen torn plantaris tendon in the mid- to distal leg. The underlying soleus muscle is normal.* ***(Right)*** *Extended field-of-view ultrasound of the same patient shows a hematoma along the line of the plantaris tendon separating the gastrocnemius and soleus muscles.*

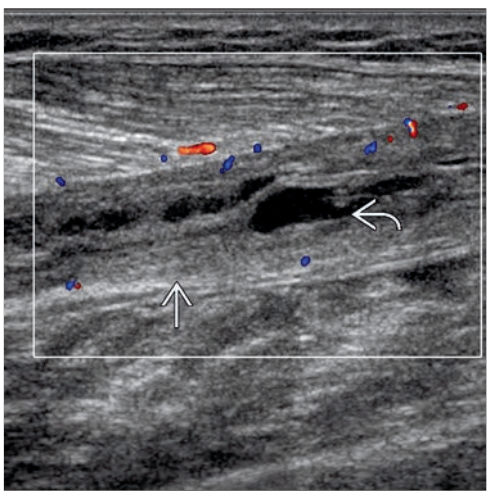


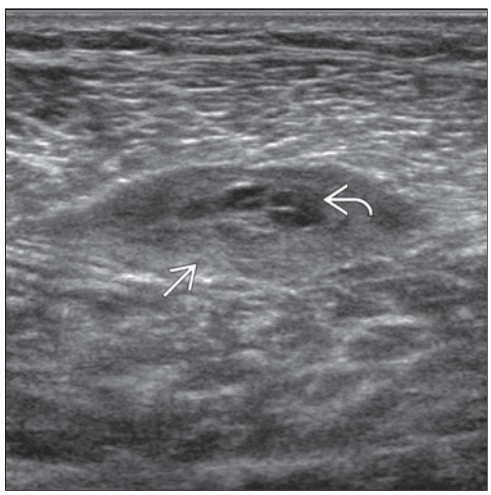




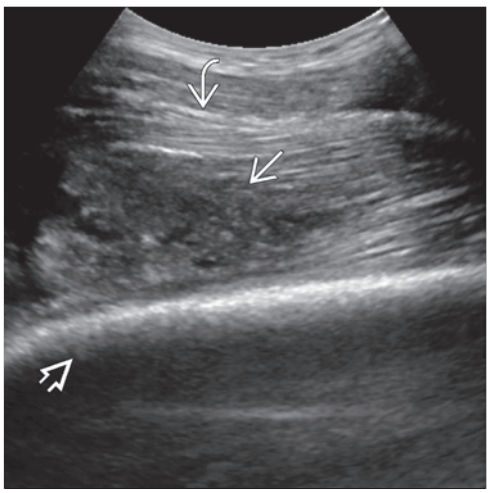


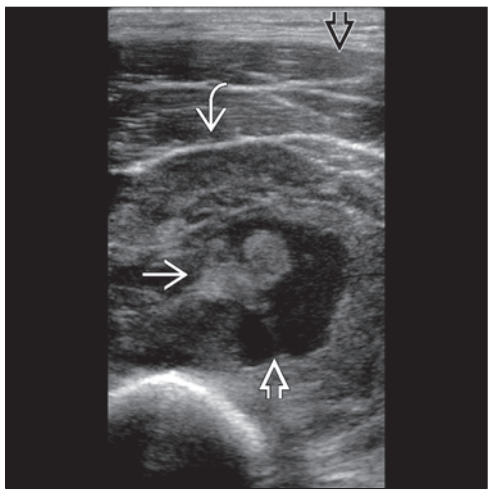
(Left) *Longitudinal ultrasound shows a moderate-sized hematoma partially stripping the myofascia between the gastrocnemius and soleus muscles as a result of a myofascial tear at the midcalf region. No liquefaction of this hematoma is present. It is difficult to exclude a plantaris tendon tear in this setting.* ***(Right)*** *Transverse ultrasound in the same patient shows a hematoma between the soleus and gastrocnemius muscles. The plantaris tendon was not visible.*





(Left) *Longitudinal color Doppler ultrasound of the same patient shows a resolving intermuscular hematoma 3 weeks later. Moderate marginal hyperemia and mild liquefaction is present.* ***(Right)*** *Transverse ultrasound of the same area shows a mild reduction in the size of the hematoma with liquefaction. Generally, there is little or no clinical benefit to following up calf muscle tears or hematomas with serial ultrasound examination, unless there are atypical clinical or imaging features.*



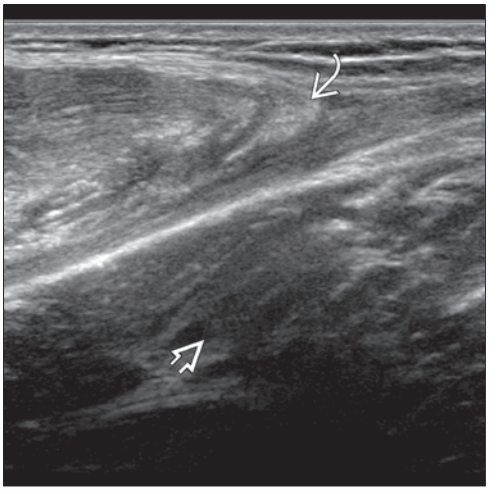


(Left) *Longitudinal ultrasound in a patient with recent leg trauma shows a severe tear at the upper to midportion of the vastus intermedius muscle. This tear occupied ~ 70% of the muscle cross-sectional area. The femoral shaft is normal.* ***(Right)*** *Transverse ultrasound of the same area shows torn vastus intermedius muscle fibers with a large intramuscular hematoma. The overlying rectus femoris muscle is normal.*

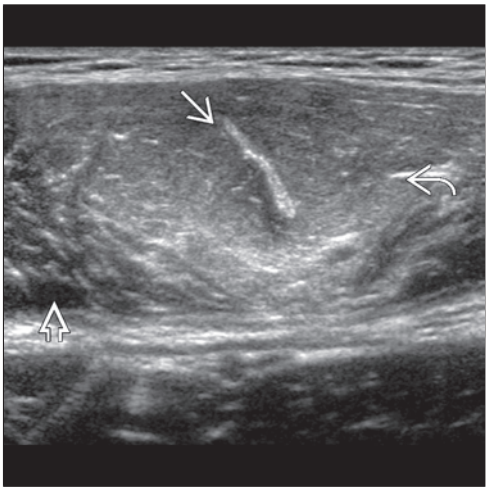
MUSCLE INJURY

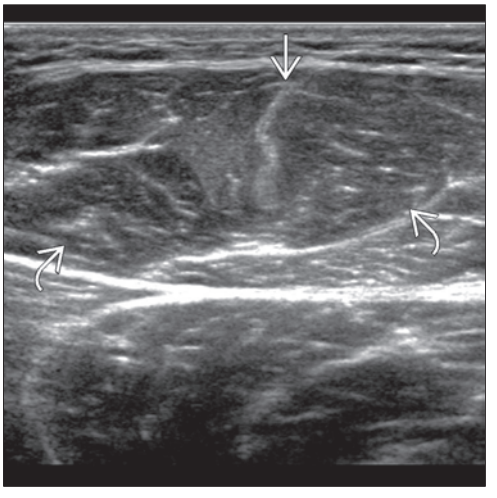
(Left) *Extended field-of-view ultrasound shows severe retraction of the rectus femoris muscle due to a tear at the quadriceps tendon junction. The underlying vastus muscles were not torn.* ***(Right)*** *Longitudinal ultrasound of the same patient shows a "clapper bell" configuration of a torn, retracted rectus femoris muscle. The underlying vastus intermedius muscle is not torn.*



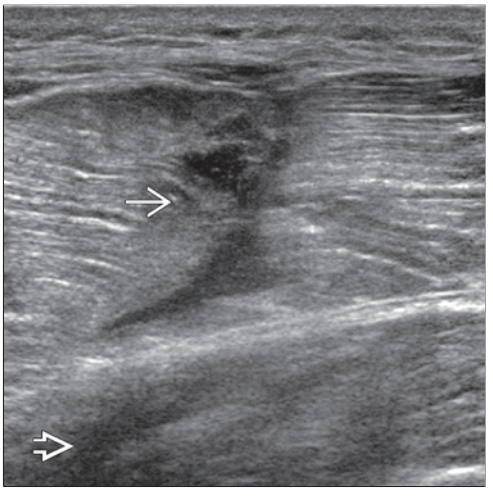


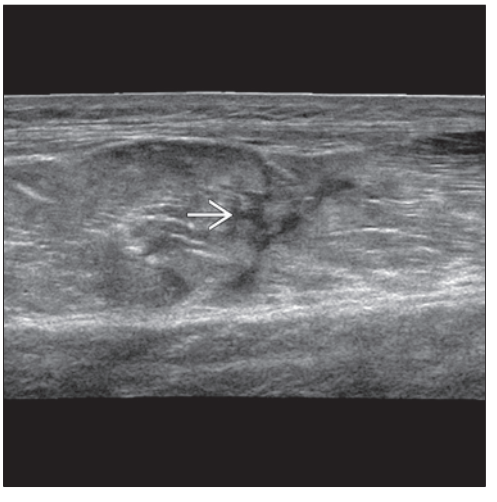
(Left) *Transverse ultrasound of the same rectus femoris muscle tear shows an amorphous appearance of a torn rectus femoris muscle around the central muscle tendon compared to the adjacent normal vastus muscle.* ***(Right)*** *Transverse ultrasound of the same patient shows a normal contralateral rectus femoris muscle around the central tendon for comparison.*

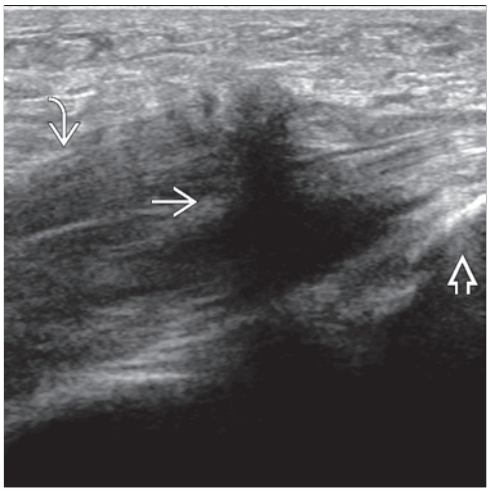


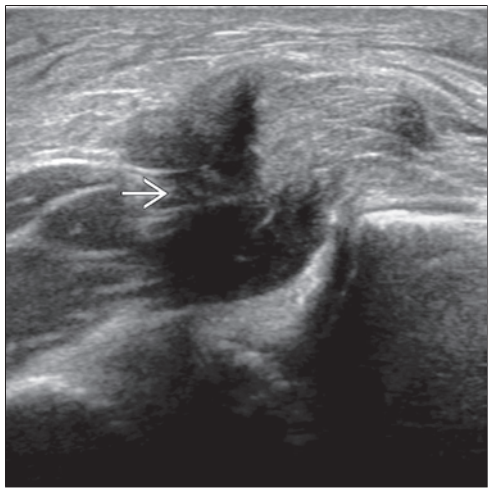


(Left) *Longitudinal ultrasound of the thigh in a patient recently kicked by a horse shows a full thickness tear in the vastus lateralis muscle of the distal thigh. The tear was associated with a surrounding hematoma and a moderate-sized knee joint effusion (not shown). The adjacent vastus intermedius muscle is normal.* ***(Right)*** *Extended field-of-view ultrasound shows the same full thickness tear of the vastus lateralis muscle. There is no muscle retraction.*

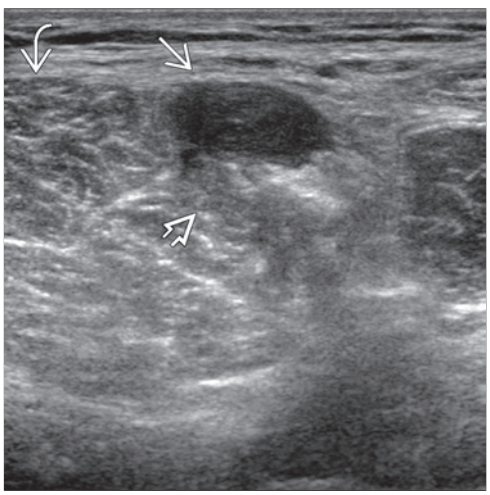


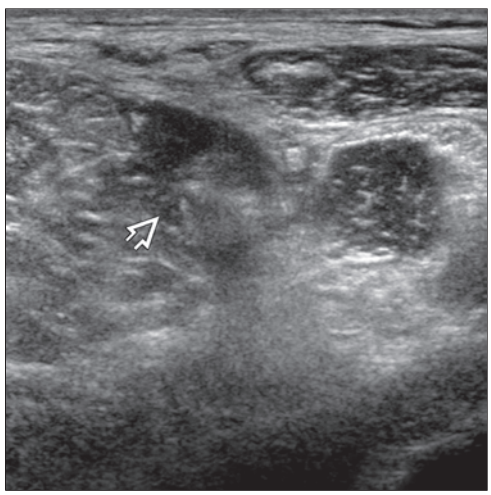




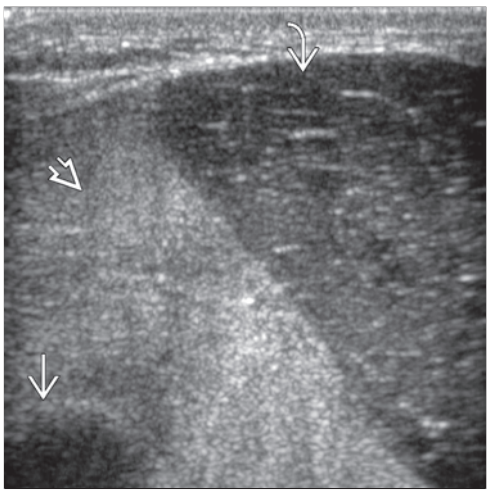


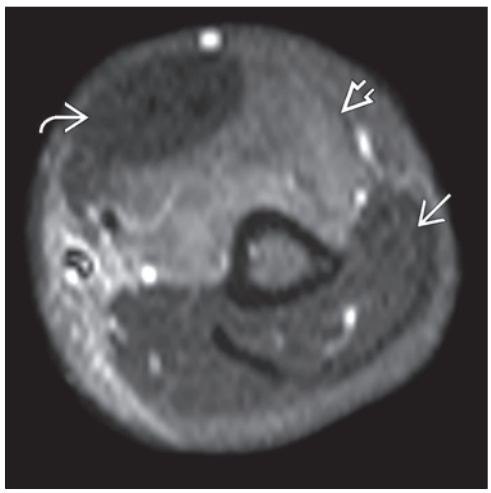
(Left) *Longitudinal ultrasound in a patient who developed pain while doing a 1-arm pull-up shows severe swelling of the distal triceps muscle and surrounding soft tissues. There is a partial full thickness tear of the distal triceps muscle where the lateral fibers insert into the central tendon just proximal to the olecranon attachment.* ***(Right)*** *Longitudinal ultrasound shows the same tear as previous image. Overall, about 30% of the triceps muscle fibers were torn.*





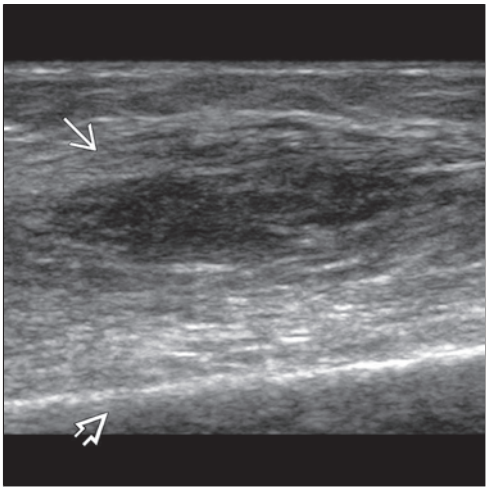
(Left) *Transverse ultrasound of the thigh in an elderly patient with blunt thigh trauma and bruising shows a small hematoma in the proximal medial portion of the tensor fascia lata muscle at the anterolateral aspect of the upper thigh. There is adjacent muscle fiber discontinuity due to a small muscle tear.* ***(Right)*** *Transverse ultrasound close to the same location shows a partial tear involving only about 5% of tensor fascia lata muscle cross-sectional area.*

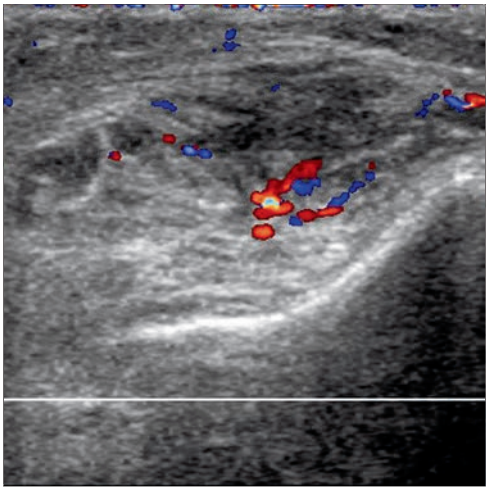




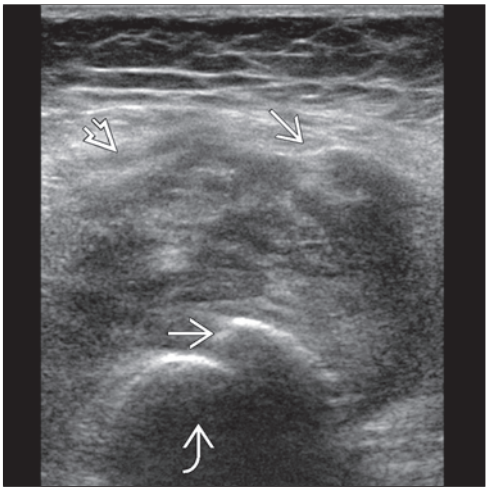
(Left) *Transverse ultrasound in a patient with unaccustomed overuse rowing injury and pain onset 1 day later shows severe edema of the brachialis muscle consistent with delayed onset muscle soreness (DOMS). The overlying biceps muscle and humeral shaft are normal.* ***(Right)*** *Axial T2WI FS MR of the same patient shows severe edema of the brachialis muscle consistent with DOMS, which is a cellular-related muscle injury. The biceps and triceps muscles are normal.*

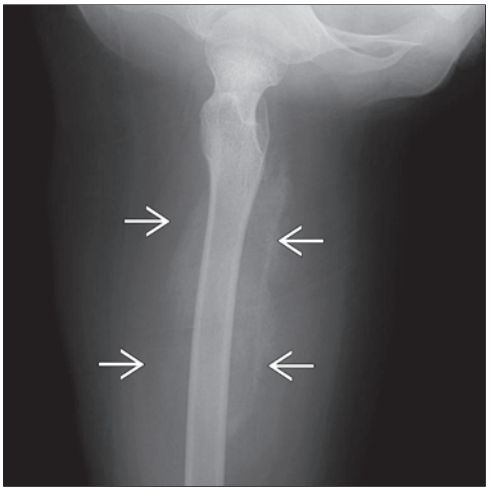
(Left) *Longitudinal ultrasound in a patient with blunt calf trauma 3 weeks earlier shows a healing muscle contusion within the peroneus longus muscle. No discrete muscle tear is evident. The fibular shaft is normal.* ***(Right)*** *Transverse ultrasound of the same area shows moderate hyperemia around the contused muscle area. The background muscle architecture is largely preserved. In another clinical context, this ultrasound appearance would fit for resolving diabetic muscle infarction.*



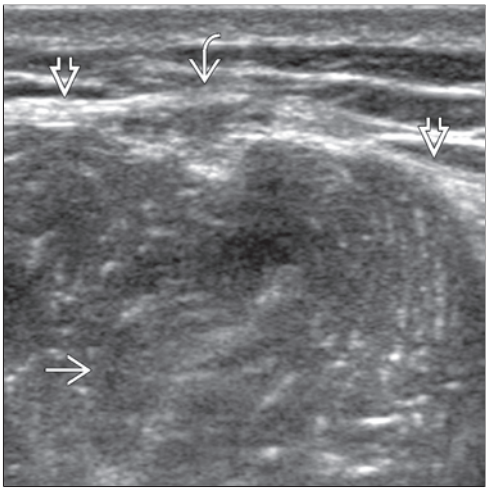


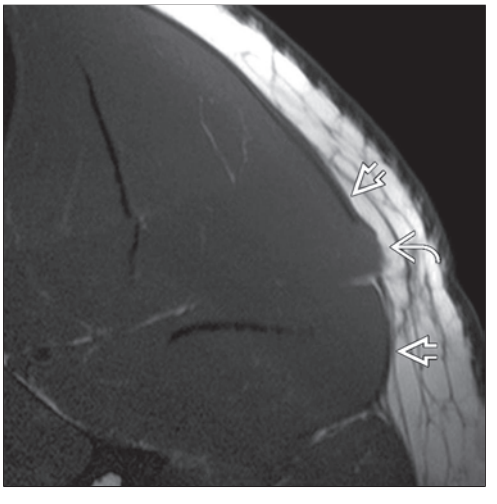
(Left) *Transverse ultrasound of the thigh in a patient 4 weeks after severe blunt thigh trauma shows a partially calcified hematoma deep in the quadratus femoris muscle and alongside the femoral shaft.* ***(Right)*** *Lateral radiograph of the same patient shows the partially ossified hematoma surrounding the proximal femoral shaft consistent with post-traumatic myositis ossificans.*

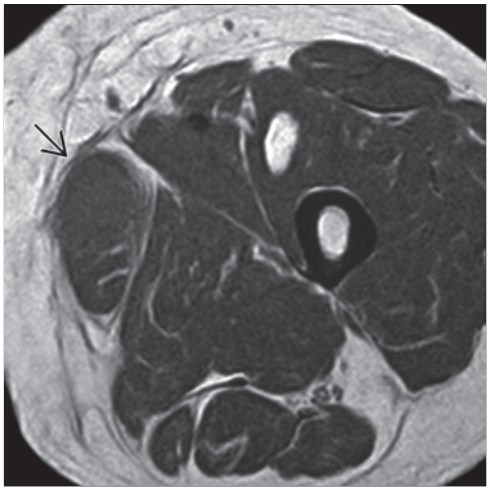


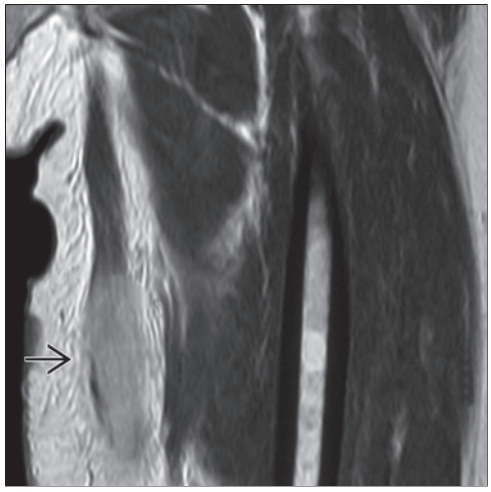


(Left) *Transverse ultrasound of a young man with anterior leg tenderness after exercise shows a small hernia of the tibialis anterior muscle extending through the investing fascia of the leg at the site of localized tenderness. Color Doppler imaging (not shown) showed a small traversing artery at this location.* ***(Right)*** *Axial T1WI MR of the same patient shows a small tibialis anterior muscle hernia extending though the investing fascia. Small muscle hernias can produce troublesome symptoms.*

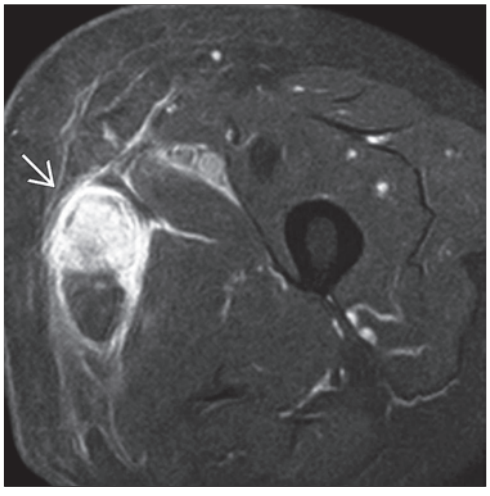


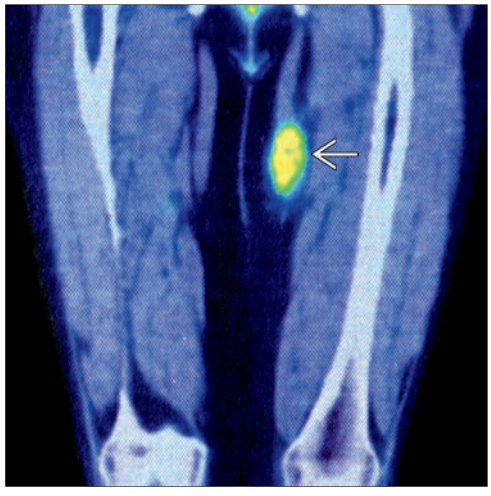




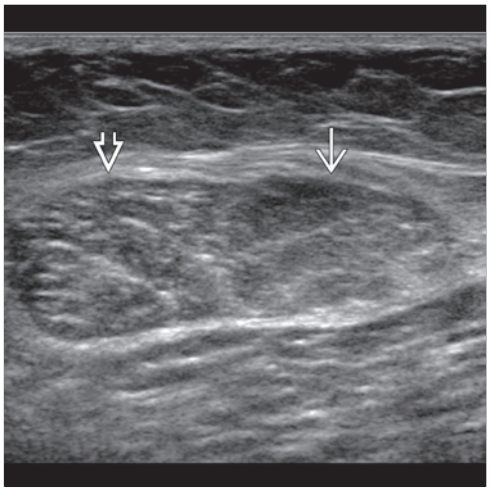


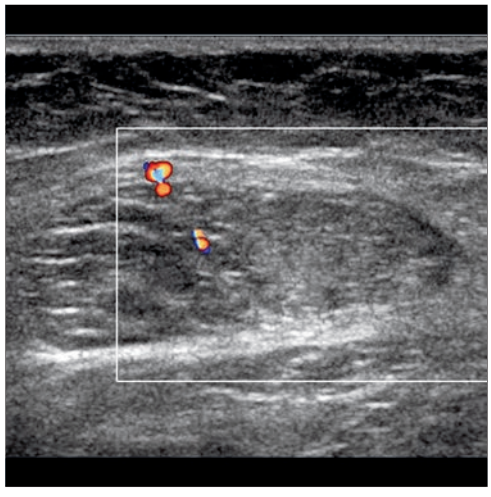
(Left) *Axial T1WI MR in a middle-aged patient with vague thigh trauma 2 months earlier shows localized isointense swelling* ⇨ *in the anterior aspect of the gracilis muscle. The remaining thigh musculature is normal.* ***(Right)*** *Coronal T2WI MR of the same lesion shows diffuse muscle edema and swelling within the middle 1/3 of the gracilis muscle* ⇨.





(Left) *Transverse T1WI C+ FS MR of the same lesion shows intense contrast enhancement* ➔ *in and around the affected area of the gracilis muscle.* ***(Right)*** *Coronal reconstructed FDG PET/CT image of the same lesion shows increased metabolic activity (standardized uptake value [SUV] 4.4) in the swollen gracilis muscle area* ➔. *Based on the MR and PET/CT appearances this was reported as a soft tissue sarcoma and an ultrasound-guided biopsy was advised.*





(Left) *Transverse ultrasound of the same lesion shows moderate swelling confined to the anterior part* ➔ *of the gracilis muscle* ➔. *The background muscle architecture is preserved. This favored a healing muscle tear with no evidence of tumor.* ***(Right)*** *Transverse color Doppler ultrasound of the same lesion shows mild perilesional hyperemia. In view of the MR and PET findings, an ultrasound-guided biopsy for histology was performed, which confirmed a healing muscle tear.*

HEMATOMA/SEROMA

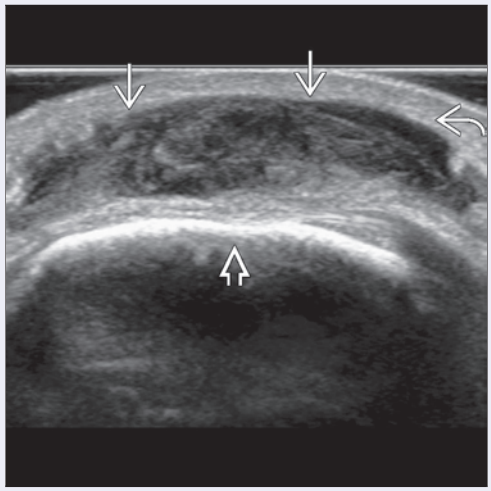
Key Facts

Imaging

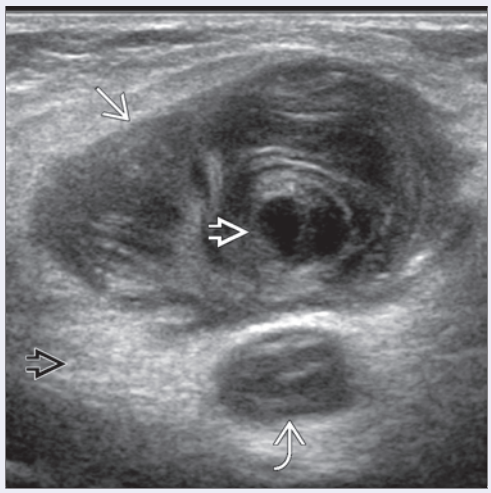
- **Hematoma acute**
  - Acute: Quite well-defined heterogeneous mass ± echogenic pseudosolid appearance
  - ± multi-laminated whorled appearance
  - ± anechoic cystic areas
  - ± echogenic foci due to gas locules
  - Surrounding soft tissue edema
  - Mild surrounding hyperemia
  - No internal hyperemia
  - Underlying cause of hematoma such as muscle tear or vascular malformation may be apparent
- **Hematoma: Subacute and chronic**
  - More well-defined margin ± distinct capsule
  - Reduces in size on serial examination
  - Hypoechoic fluid areas due to separation of serum from cellular elements in the process of liquefaction
  - Mild marginal hyperemia on color Doppler imaging
  - ± more central hyperemia if of long duration
- **Organizing hematoma**
  - Encapsulated, increasing size due to recurrent bleeding, internal hyperemia
  - May simulate soft tumor
  - May require biopsy to differentiate
- **Seroma**
  - Often close to site of surgery (chest wall, abdomen, groin)
  - Echo-poor or anechoic with strong posterior acoustic enhancement
  - Usually no wall or barely discernible wall depending on chronicity
- **Lymphocele**
  - Close to site of vascular surgery
  - Very similar ultrasound appearances to seroma
  - Different etiology than seroma

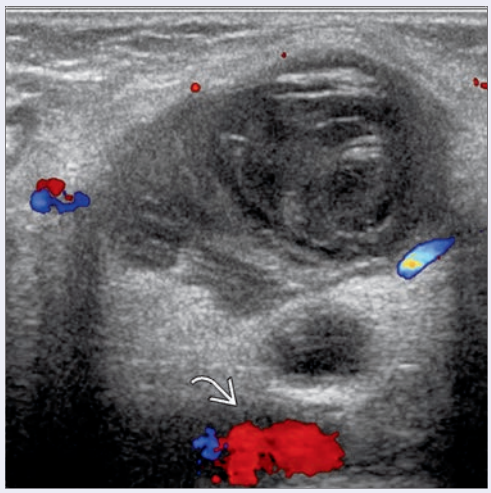
(Left) *Clinical photograph shows a patient with an acute knee injury associated with pre-patellar soft tissue swelling, abrasions, and bruises.* ***(Right)*** *Transverse ultrasound of the same patient shows a medium-sized acute subcutaneous hematoma anterior to the patella. The hematoma shows a heterogeneous, hypoechoic, pseudosolid appearance. A more fluid component is present at the superficial aspect of the hematoma.*





(Left) *Transverse ultrasound of the groin 2 days after arterial puncture shows a large, well-defined, oval-shaped hematoma. The hematoma shows a typical multilaminated whorled appearance with posterior enhancement and a central anechoic fluid component. Another smaller hematoma is present posteriorly. A moderate degree of surrounding edema is present.* ***(Right)*** *Transverse color Doppler ultrasound of the same location shows no internal vascularity. The femoral artery is located posteriorly.*





HEMATOMA/SEROMA

TERMINOLOGY

Definitions
- Hematoma: Localized collection of blood outside of blood vessel
- Seroma: Serous fluid collection within soft tissues
- Lymphocele: Collection of lymphatic fluid due to leakage from lymphatics

IMAGING

General Features
- Best diagnostic clue
  - Hematoma: Solid echogenic mass with small cystic areas and no internal hyperemia
    - Often history of trauma
  - Seroma: Anechoic fluid collection ± internal debris; minimal or no wall hyperemia
    - Nearby surgery
  - Lymphocele: Anechoic fluid collection, no internal debris, no wall hyperemia
    - Nearby vascular surgery
    - Often very difficult to distinguish seroma from lymphocele
- Location
  - Hematoma: Usually at site of trauma
  - Seroma: Chest wall, abdominal wall, or groin
  - Lymphocele: Both central and peripheral sites
- Size
  - Variable
  - Large in buttock or thigh
  - Smaller in chest wall, abdominal wall, and periphery

Radiographic Findings
- Radiography
  - Soft tissue and mildly hyperdense opacity and swelling
    - ± calcification in old hematoma

MR Findings
- T1WI
  - Hematoma
    - Acute: Isointense on T1WI; variable hyper- to hypointense on T2WI
    - Subacute/chronic: Hyperintense on T1WI and T2WI
    - T2* GRE: Hemosiderin deposition with susceptibility blooming artifact
  - Seroma/lymphocele
    - Fluid-like collection near site of surgery

Ultrasonographic Findings
- Hematoma
  - Appearances depend on chronicity
  - Internal echogenicity depends on degree of blood coagulation, liquefaction, and organization
    - Acute: Quite well-defined heterogeneous mass in subcutaneous or muscle layer
      - ± echogenic pseudosolid appearance
      - ± multi-laminated whorled appearance
      - ± anechoic cystic areas
      - ± echogenic foci due to gas locules
      - Surrounding soft tissue edema
      - Usually no surrounding hyperemia in hyperacute stage; develops over a few days
      - No internal hyperemia
      - Mild acoustic enhancement
      - Underlying cause of hematoma, such as muscle tear or vascular malformation, may be apparent
    - Subacute & chronic: Well defined, variable echogenicity depending on liquefaction and degree of blood clot organization
      - More well-defined margin ± distinct capsule
      - Reduces in size on serial examination
      - Hypoechoic fluid areas due to separation of serum from cellular elements in the process of liquefaction
      - Mild marginal hyperemia usually on color Doppler imaging
      - ± more central hyperemia if hematoma is of long duration
      - May remain avascular
      - ± marginal calcification
      - Acoustic enhancement if liquefaction
      - Acoustic shadowing if calcification or fibrosis
      - Underlying cause may become more apparent
    - Organizing hematoma
      - May simulate soft tumor
      - Encapsulated, increasing size due to recurrent internal bleeding, internal hyperemia
      - Neovascularization, although present, may not show on color Doppler imaging due to small size of neovascular structures
      - May require biopsy to differentiate
    - Hemophiliac pseudotumor
      - Organizing hematoma of hemophilia
      - Thick-walled hematoma with internal vascularity
      - Can grow due to repeated bleeding
      - Mass effect with bone scalloping
      - Usually in soft tissues but can be subperiosteal or intraosseous
      - 1-2% of all hemophiliacs
    - Rectus sheath hematoma
      - Above arcuate line: Ovoid in shape with long axis superoinferior; localized to 1 side
      - Below arcuate line: No linea alba so can cross midline; pad-like with transverse long axis
- Seroma
  - Often close to site of surgery (chest wall, abdomen, groin)
  - Ultrasound appearances vary with chronicity and content of seroma
  - Echo-poor with strong posterior acoustic enhancement
  - Acute seroma
    - Usually anechoic because of sterile fluid content
    - Usually no wall or barely discernible wall depending on chronicity
    - No adjacent soft tissue edema or hyperemia
    - No internal echogenic component unless complicated by hemorrhage
    - Ultrasound-guided aspiration yields clear or pale straw-colored fluid
  - Chronic seroma
    - ± increasing echogenicity of content ± fibrous septa
    - ± increasing wall thickness and mild hyperemia

HEMATOMA/SEROMA

- Can be difficult to distinguish between chronic seroma and chronic liquefied hematoma
- Lymphocele
  - Close to site of vascular surgery
  - Very similar ultrasound appearances to seroma
    - Etiology of seroma and lymphocele is different
  - Ultrasound-guided aspiration yields clear or pale straw-colored fluid
    - Laboratory analysis yields slight increase in lymphocyte count
    - Chylous fluid (↑ triglyceride and protein count) is feature of high retroperitoneal and thoracic lymphoceles only
    - Not a feature of peripheral lymphoceles

Imaging Recommendations

- Best imaging tool
  - Ultrasound can make distinction between hematoma and seroma/lymphocele
  - Serial follow-up helpful to confirm hematoma and to check for underlying cause
    - MR may provide additional help in assessing underlying trauma or vascular malformation
  - Percutaneous aspiration can help distinguish seroma/lymphocele and low-grade infection (e.g., fungal infection)
    - Increased lymphocyte count in lymphocele
    - Lymphoscintigraphy may also be helpful in showing lymphatic channel disruption and collateral pathways
- Protocol advice
  - Correlate closely with clinical history
  - Always include evaluation with color Doppler
  - Check for underlying cause if hematoma
  - Check for signs of any infection

DIFFERENTIAL DIAGNOSIS

Soft Tissue Mass/Sarcoma

- Predominantly solid in appearance
- Usually more internal vascularity
- Enlarging clinically or on serial examination
- No trauma or surgical history

Low-Grade Abscess

- Thicker walls ± internal septation
- Internal debris with variable amount of internal echoes ± gas locules
- Adjacent soft tissue edema and hyperemia
- ± sinus tract

PATHOLOGY

General Features

- Etiology
  - Hematoma: Blood leakage from vasculature
    - Spontaneous hematoma
      - Underlying bleeding tendency (e.g., hemophilia, anticoagulant therapy, aspirin)
      - Unrecognized trivial trauma such as severe coughing or sneezing
      - Rectus sheath hematoma due to inferior epigastric vessel constriction during physical exertion
  - Seroma: Serous exudate from serous membrane
    - Generally occurs following surgery of chest, abdomen, or groin

Gross Pathologic & Surgical Features

- Hematoma: Weeks later, more progressive hemolysis and liquefaction
  - Chronic hematoma can have multi-laminated concentric appearance due to repeated bleeding
  - Months later, hematoma completely resolves

CLINICAL ISSUES

Presentation

- Most common signs/symptoms
  - Localized swelling
  - Hematoma: Bruising or bluish discoloration of skin
- Other signs/symptoms
  - Fever, tenderness, redness, and increased warmth
  - Abnormal clotting profile and thrombocytopenia if bleeding tendency

Demographics

- Age
  - Any age
  - Probably more common in elderly due to impaired clotting profile (hematoma) and increasing likelihood of surgery (seroma/lymphocele)
- Gender
  - Rectus sheath hematoma: More common in females; may be due to weaker rectus muscles

Natural History & Prognosis

- Hematoma and seroma/lymphocele usually resolve gradually over 2-6 months

Treatment

- Hematoma
  - Rest, ice, compression, and elevation (RICE)
  - Restrain from intense physical activity
  - Analgesia
  - Intravenous fluid resuscitation/blood transfusion
  - Correction of coagulopathy (e.g., stop anticoagulant, infusion of fresh frozen plasma, platelet concentrates)
  - Aspiration if liquefied
- Seroma/lymphocele
  - Ultrasound-guided aspiration or drainage
  - Pressure bandaging

DIAGNOSTIC CHECKLIST

Consider

- Infection if adjacent soft tissue hyperemia and edema

Image Interpretation Pearls

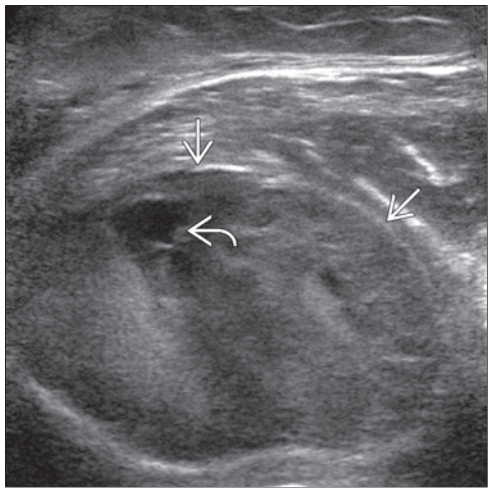
- Correlation with clinical history very important
- Always evaluate with color Doppler imaging

SELECTED REFERENCES

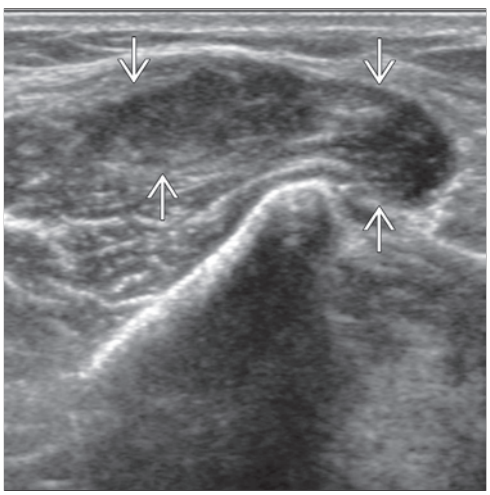
1. Lee RK et al: Ultrasound of the abdominal wall and groin. Can Assoc Radiol J. 64(4):295-305, 2013
2. Gokhale S: Sonography in identification of abdominal wall lesions presenting as palpable masses. J Ultrasound Med. 25(9):1199-209, 2006

HEMATOMA/SEROMA





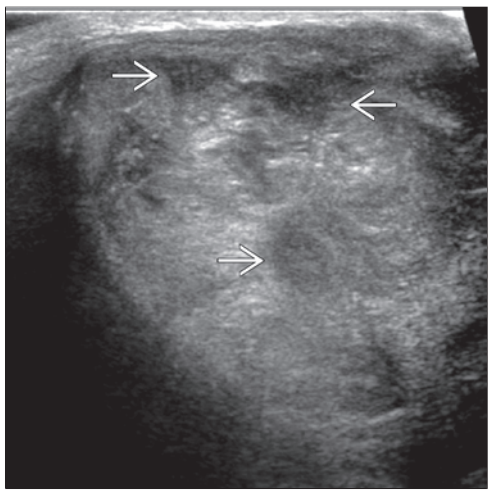
(Left) *Clinical photograph shows a patient on warfarin with spontaneous swelling and bruising on the lateral side of the lower thigh and knee.* ***(Right)*** *Transverse ultrasound of the same patient shows a large, well-defined hematoma within the vastus lateralis muscle. A small anechoic cystic area due to liquefaction is present more superiorly.*





(Left) *Longitudinal ultrasound shows the elbow region of a patient with a history of trauma 1 month prior. There is a small, ill-defined, hypoechoic mass at the lateral aspect of triceps muscle . This is consistent with intramuscular hematoma. No discrete tear is evident.* ***(Right)*** *Longitudinal color Doppler ultrasound at the same location as previous image shows minimal peripheral vascularity and no internal vascularity. Biopsy confirmed a chronic hematoma.*

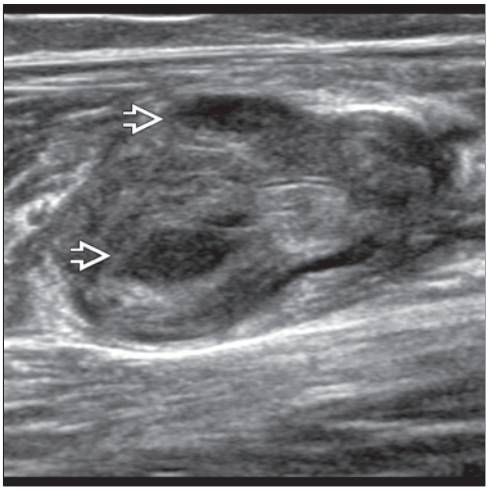


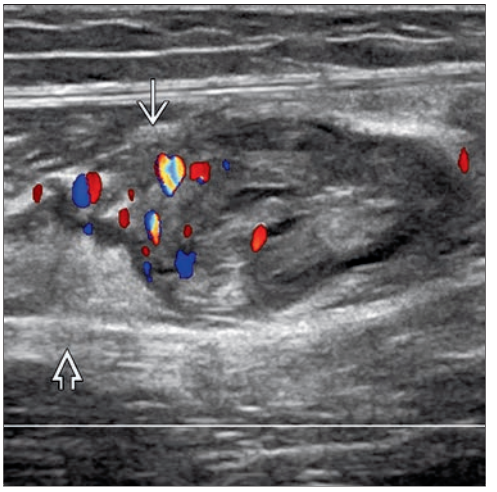


(Left) *Clinical photograph shows a patient with spontaneous painful swelling of the iliac crest region , which had been increasing for 6 months with no history of trauma.* ***(Right)*** *Transverse ultrasound of the same patient shows a largely solid mass in the subcutaneous tissue above the iliac crest. The lesion is well encapsulated with no calcification. Small hypoechoic areas are present within the mass . This is consistent with an expanding hematoma, which was confirmed by percutaneous biopsy.*

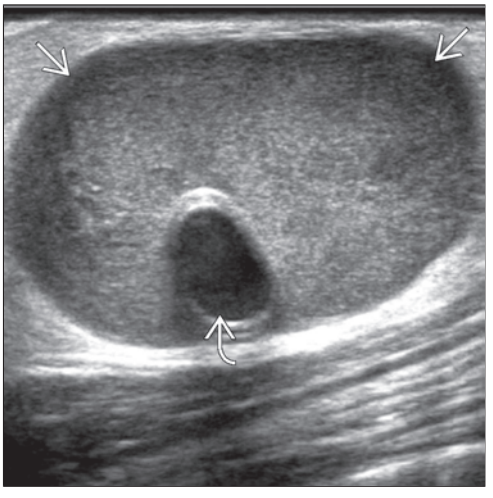
HEMATOMA/SEROMA

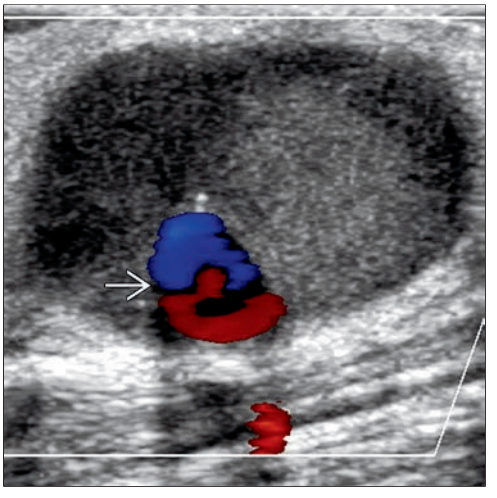
(Left) *Longitudinal ultrasound shows the calf in a patient with spontaneous swelling. Note large, well-defined, oval-shaped mass with multilaminated whorled appearance and mild posterior enhancement, consistent with a hematoma. Small liquefied areas are seen within the hematoma. No discrete tear or vascular malformation is seen.* ***(Right)*** *Color Doppler ultrasound, same mass, shows increased vascularity eccentrically within the mass, suggestive of underlying vascular anomaly. Note surrounding edema.*



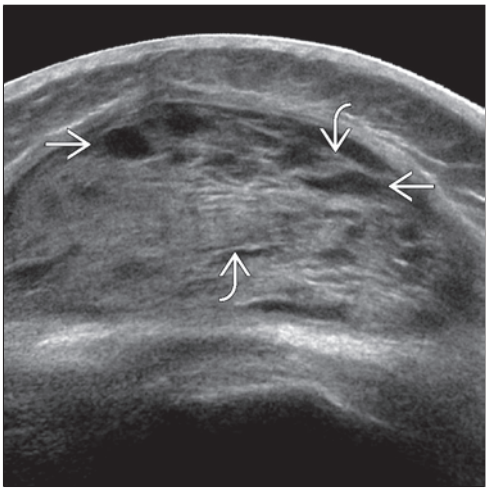


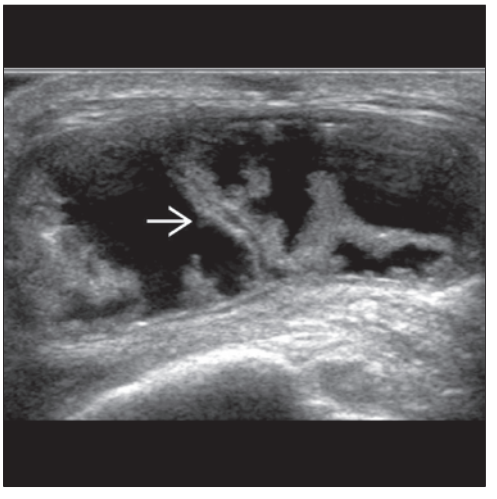
(Left) *Transverse ultrasound shows the groin in a patient with arteriovenous graft connecting the saphenous vein and femoral artery. A large mass with low-level internal echoes surrounding the graft is consistent with an encapsulated hematoma.* ***(Right)*** *Transverse color Doppler ultrasound shows the typical "yin-yang" sign of an arteriovenous graft. No vascular signal is demonstrated within the surrounding hematoma.*

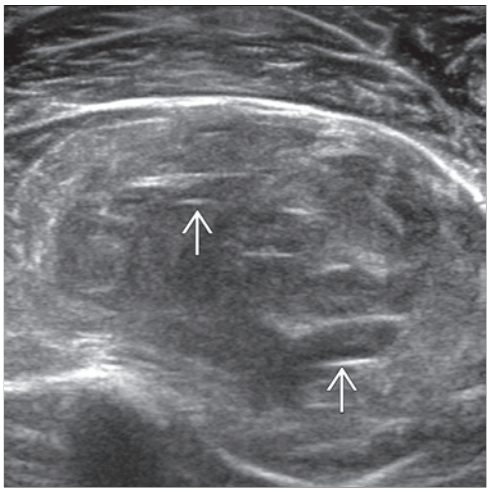


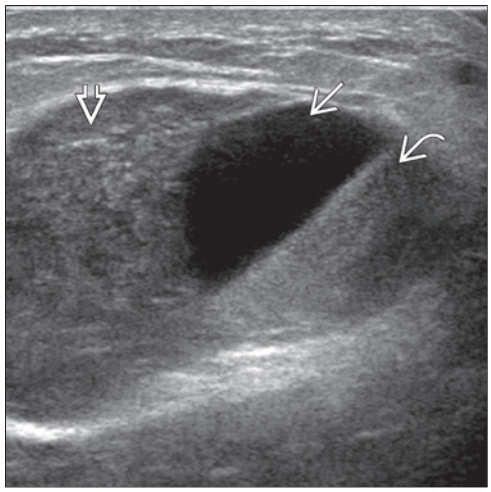


(Left) *Longitudinal ultrasound of the proximal thigh after total hip arthroplasty shows a well-defined mass with layering, anechoic liquefied areas and internal septations. Features are consistent with a resolving large hematoma.* ***(Right)*** *Transverse ultrasound of the same region 1 month later shows increased liquefaction of the hematoma with a greater cystic component, septae, and fibrin clots. Features are consistent with liquefying hematoma.*

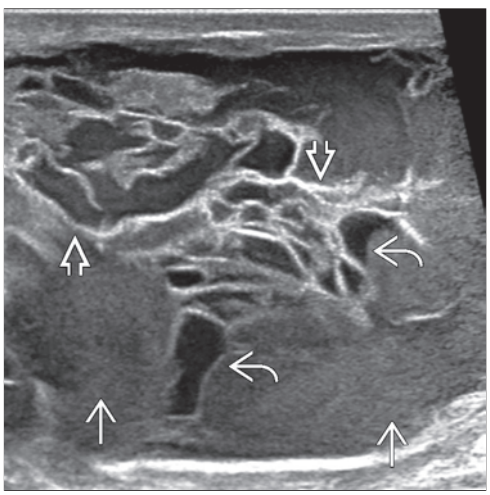


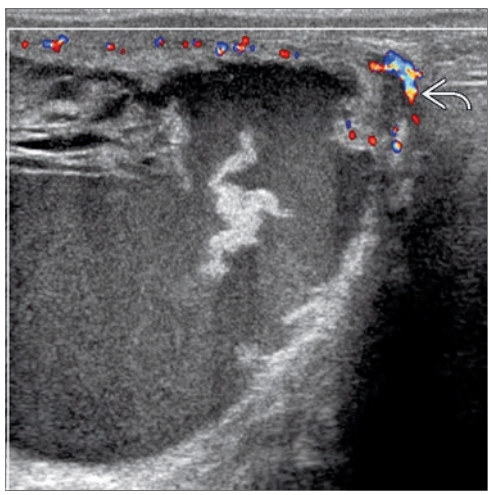




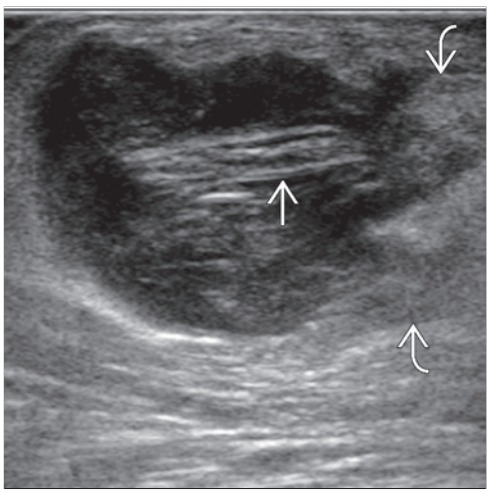


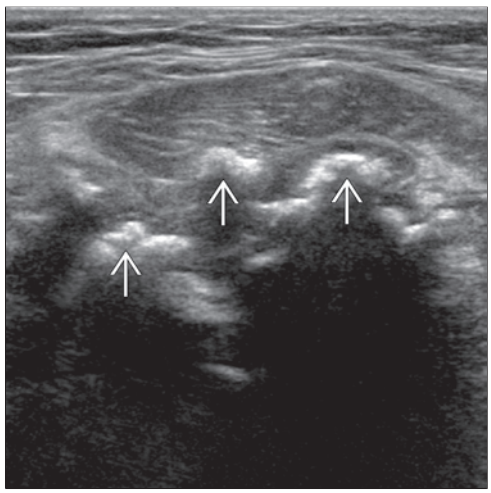
(Left) *Transverse ultrasound of the calf 3 days following blunt trauma shows a large hematoma within the soleus muscle belly. Layering is present within the more liquefied portions.* ***(Right)*** *Transverse ultrasound of the medial aspect of the knee shows a large subcutaneous cystic collection with fluid-fluid levels. This hematoma is composed of an echogenic blood clot, a clear liquefied serous component, and a more dependent cellular component.*





(Left) *Transverse ultrasound of the buttock region shows a large cystic mass with low-level fine internal echoes, hyperechoic fibrous septations, and anechoic areas suggestive of an almost completely liquefied hematoma.* ***(Right)*** *Transverse color Doppler ultrasound of the same lesion shows mild peripheral vascularity. This is consistent with chronic liquefied hematoma. Aspiration yielded old blood.*



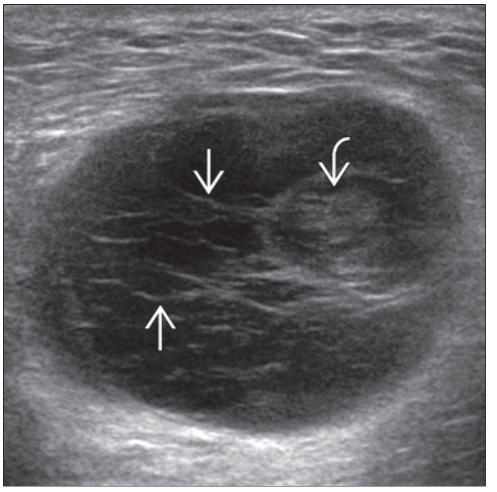


(Left) *Longitudinal ultrasound of a calf in an anticoagulated patient with spontaneous swelling shows a medium-sized hematoma with fibrinous-type layering confined to the subcutaneous tissues. Moderate surrounding soft-tissue edema is present.* ***(Right)*** *Transverse ultrasound of the thigh following a road traffic accident several months previously shows a large heavily calcified mass with peripheral calcification obscuring more posterior detail. CT confirmed a large calcified hematoma.*

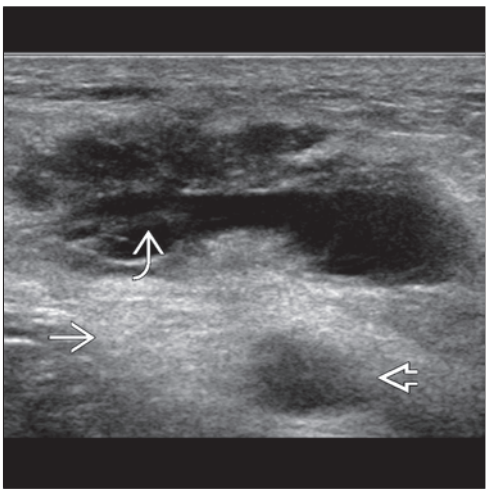
HEMATOMA/SEROMA

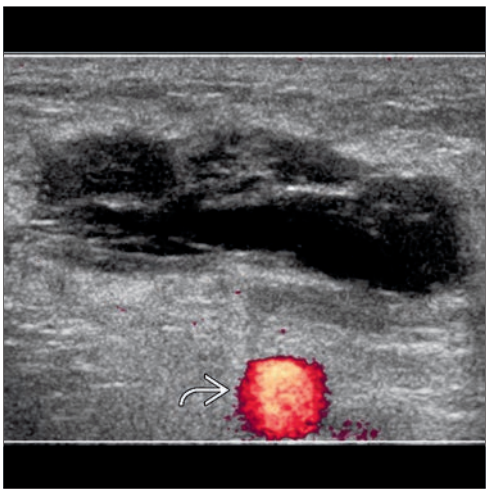
(Left) *Clinical photograph shows a groin swelling* ⇨ *at the site of a scar due to inguinal hernia repair 2 months previously.* ***(Right)*** *Longitudinal oblique ultrasound in the same patient shows an oval-shaped, well-defined collection within the inguinal canal. The mass contains predominantly cystic components with multiple thin internal septations* ➔ *and small areas of more solid material* ➔. *Features are compatible with a chronic seroma.*



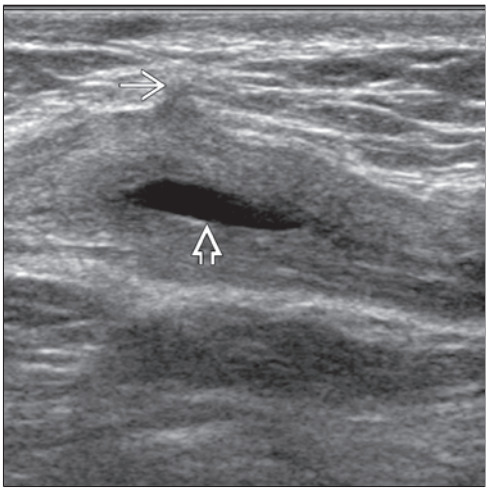


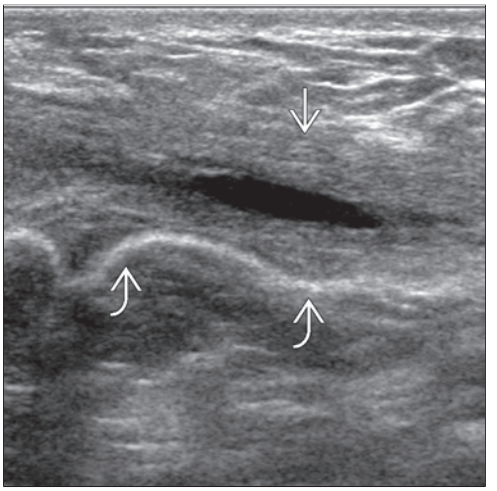
(Left) *Transverse ultrasound of the groin after surgery shows a cystic lesion with internal septation* ➔. *Moderate adjacent soft-tissue edema and mild posterior acoustic enhancement* ➔ *is present. The common femoral artery* ➔ *is situated posteriorly. Features are consistent with a postoperative seroma.* ***(Right)*** *Transverse color Doppler ultrasound of the same mass shows no vascularity within the lesion or perilesional soft tissues. Note the normal vascular signal within the femoral artery* ➔.

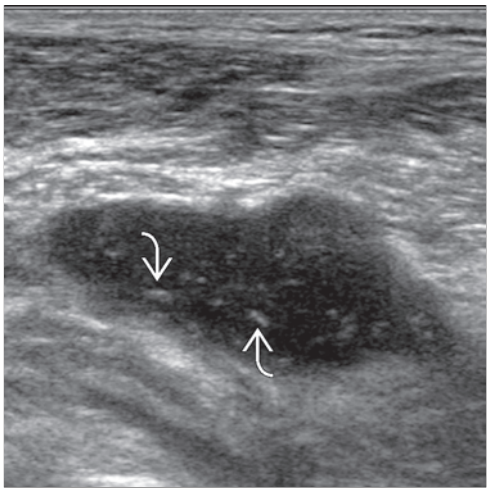


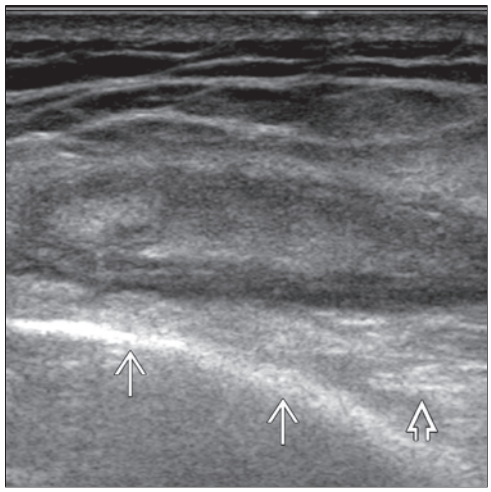


(Left) *Transverse ultrasound of the groin 3 months after incisional hernia repair shows a thick-walled cystic area present at the deep wound edge* ➔. *There is a small anechoic central cystic component* ➔. *The appearances are suggestive of an chronic organizing seroma.* ***(Right)*** *Transverse ultrasound just distal to the previous image shows that the thick-walled seroma* ➔ *containing anechoic fluid is located anterior to the surgical mesh* ➔.

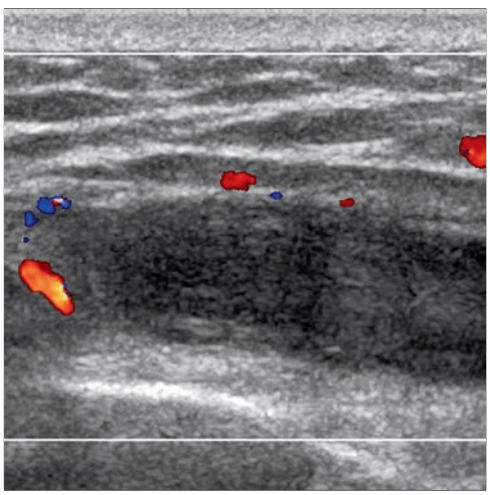


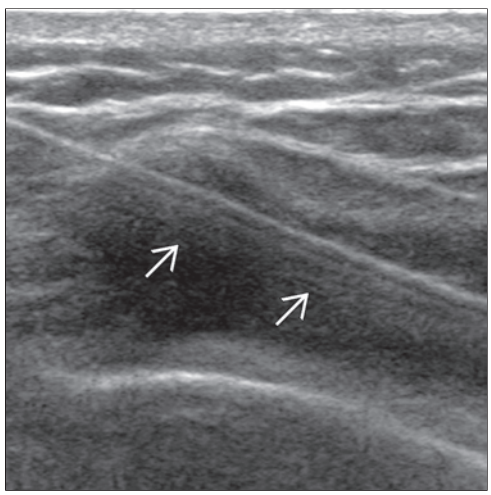




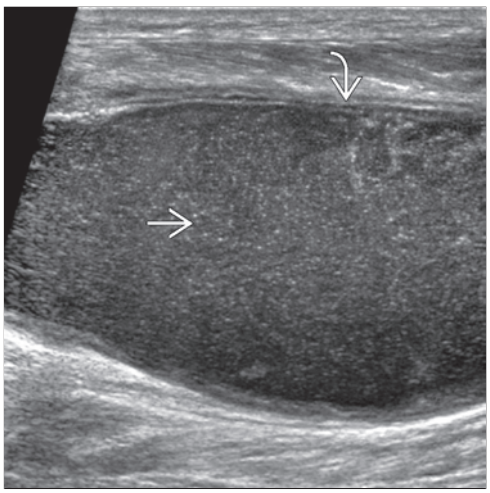


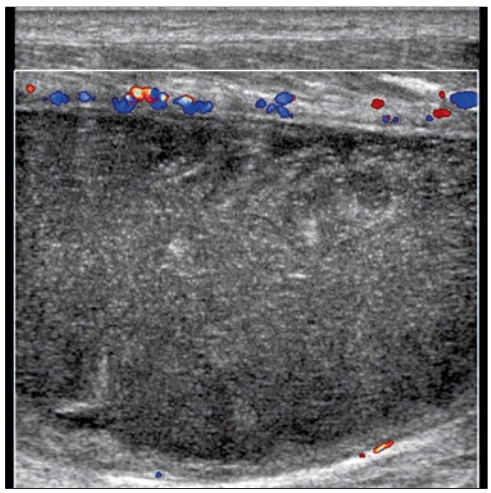
(Left) *Transverse ultrasound of the medial aspect of the popliteal fossa 3 months after knee operation. This shows a well-defined cystic lesion with small echogenic foci and no discernible wall. Appearances are consistent with a lymphocele.* ***(Right)*** *Longitudinal ultrasound shows the scapular region in a patient with a history of septic arthritis and surgical drainage. There is a hypoechoic mass overlying the infraspinatus muscle, consistent with a resolving collection.*





(Left) *Longitudinal color Doppler ultrasound of the same mass shows moderate surrounding hyperemia but no central hyperemia. Appearances are consistent with an organizing postoperative collection.* ***(Right)*** *Ultrasound-guided fine-needle aspiration of the same lesion could only aspirate a small amount of blood-stained fluid. Most of the content was viscous and could not be aspirated. Laboratory confirmed hemorrhage without bacteria. Note the reverberation artifacts posterior to the needle.*





(Left) *Longitudinal ultrasound of the calf in a patient with end-stage renal failure shows multiple echogenic speckles and a well-defined wall, consistent with an abscess rather than a seroma, lymphocele, or liquefied hematoma. Aspiration yielded purulent fluid.* ***(Right)*** *Longitudinal color Doppler ultrasound of same lesion shows mild peripheral hyperemia. The size of intrinsic echogenic speckles is indicative of an abscess rather than seroma, lymphocele, or liquefied hematoma.*

LIGAMENT INJURY

Key Facts

Terminology
- Ligament tear: Tear or avulsion of ligament fibers

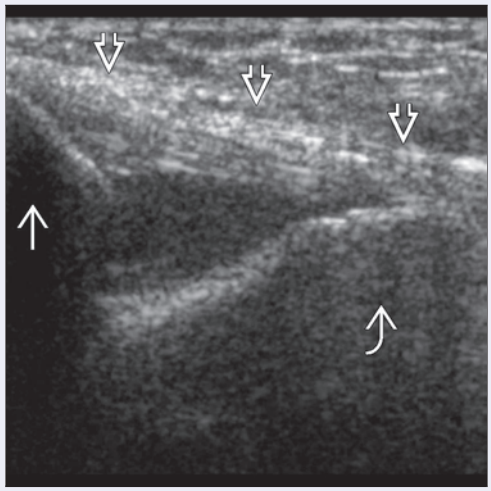
Imaging
- Ligament tears have same appearance irrespective of ligament location
- Acute stage
  - Diffuse or localized ligament swelling
  - Ligament fiber discontinuity with hypoechoic gap at site of tear
  - Surrounding soft tissue subcutaneous edema, hemorrhage, and hyperemia
- Chronic stage: 4 possible sequelae of ligament tear exist
  - Diffusely thickened continuous ligament
  - Diffusely thickened discontinuous ligament
  - Diffusely attenuated ligament
  - Absent ligament

Pathology
- Grade 1: Mild partial ligament tear
- Grade 2: Moderate to severe partial ligament tear
- Grade 3: Complete ligament tear or avulsion
- Inflammatory phase: Bleeding → platelet-rich fibrin clot → release growth factors → repair stimulation
  - Begins immediately after injury and lasts for 72 h
- Proliferative phase: Fibroblasts → disorganized scar tissue and proteoglycan filling ligament gap → progressive remodeling
- Reparative phase: Progressive collagen maturation
- Healed ligament is morphologically, biochemically, and functionally inferior to normal ligament

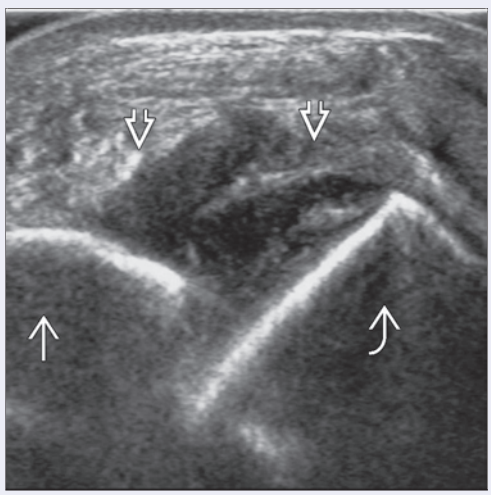
Clinical Issues
- Most frequent musculoskeletal injury
- Leads to instability, impingement, dystrophic calcification, or contracture

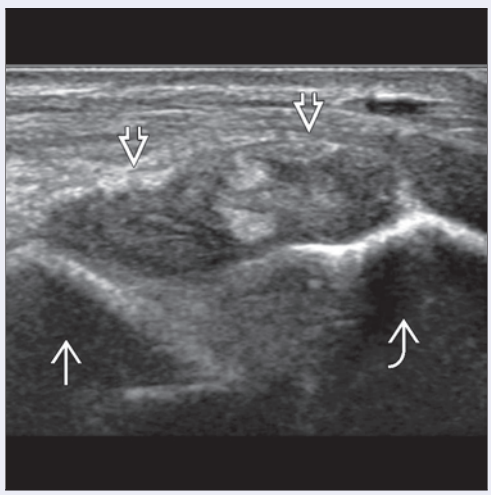
(Left) *Clinical photograph shows probe orientation for examining the anterior talofibular ligament (ATFL). The ankle is slightly plantar flexed and the probe orientation is transverse.* ***(Right)*** *Transverse ultrasound of the anterolateral ankle in the same patient shows normal intact ATFL coursing between the fibula and talus. Note how the ligament is echogenic and taut with continuity of fibers.*





(Left) *Transverse ultrasound of the lateral ankle region shows an acute complete (grade 3) tear of the ATFL with loss of fibers in between the talus and the fibula. Hematoma fills up the gap.* ***(Right)*** *Transverse ultrasound of the lateral ankle region shows an acute complete (grade 3) tear of the ATFL with loss of the normal fibers between the talus and the fibula. The intervening gap is partially filled by hematoma.*





LIGAMENT INJURY

TERMINOLOGY

Abbreviations
- Ulnar collateral ligament (UCL), radial collateral ligament (RCL), medial collateral ligament (MCL), anterior talofibular ligament (ATFL), calcaneofibular ligament (CFL), anterior tibiofibular ligament (ATibFL)

Synonyms
- Skier's or gamekeeper's thumb: Injury of UCL of thumb; Stener lesion: Proximal retraction of UCL that comes to overlie adductor aponeurosis, ligament sprain or strain

Definitions
- Ligament: Fibrous band that connects 2 bones and helps stabilize intervening joint
- Ligament tear: Tear or avulsion of ligament fibers
- Avulsion: Some or all of the ligament fibers are torn away (avulsed) from their bony attachment
  - ± attached avulsed fragment of bone (avulsion fracture)
- Ligament sprain or strain: Partial ligament tear

IMAGING

General Features
- Best diagnostic clue
  - Discontinuity of ligament fibers
- Location
  - Some ligaments are more susceptible to tear
    - Ankle
      - ATFL: Anywhere along course of ligament
      - CFL: Anywhere along course of ligament
      - ATibFL: Anywhere along course of ligament
      - Deltoid ligament: Particularly anterior deep fibers
    - Knee
      - MCL: Anterior fibers at femoral attachment
      - Anterior cruciate ligament: Fibers close to femoral attachment
      - Posterior cruciate ligament: Anywhere along course of ligament
    - Thumb
      - UCL of metacarpophalangeal (MCP) joint: Particularly phalangeal attachment
    - Elbow
      - Lateral collateral ligament (LCL): Particularly near humeral attachment
- Size
  - Partial or complete
- Morphology
  - Ligament is composed of 2/3 water, 1/3 solid tissue
  - Solid component is mainly (85%) type I collagen
  - Ligaments consist of bundles of collagen fibers (composed of smaller collagen fibrils) aligned parallel along ligament
    - Collagen fibers are cross linked and, if not under tension, undulate along long axis of ligament
    - Fibroblasts and proteoglycans reside in extracellular matrix between collagen fibers
    - Ligaments are covered by epiligament that contains vessels, pain and proprioceptive nerve endings, and mechanoreceptors (Ruffini endings, Pacinian corpuscles, Golgi tendon organs)
      - Neural elements of epiligament are particularly abundant close to bony insertion
      - Initiate protective feedback reflexes that activate muscles around joints

Radiographic Findings
- Soft tissue swelling ± joint effusion
  - ± avulsion fracture at ligament insertional area
  - ± diastasis of opposing bone margins
- Stress radiographs
  - Less frequently used in modern practice
  - Mainly indicate complete ligament tear
  - ATFL complete tear → increased tibiotalar tilt

Ultrasonographic Findings
- All ligament injuries have same appearance irrespective of where ligament is located
- Acute stage
  - Diffuse or localized ligament swelling
  - Ligament fiber discontinuity with hypoechoic gap at site of tear
    - Tear can be partial or full thickness
    - ± avulsion fracture at bony attachment
  - Ligament retraction if complete
    - ± wavy, displaced ligament
    - Widening of ligament tear or joint space when ligament is stressed
  - Surrounding soft tissue edema and hemorrhage
  - Surrounding soft tissue hyperemia on color Doppler
  - Variably sized joint effusion
- Chronic stage: 4 possible sequelae of ligament tear exist
  - Diffusely thickened continuous ligament
    - Most common sequela of ligament tear
    - Can remain for many years or even forever following injury
    - Disorganized reparative tissue undergoing gradual remodeling
    - Even initially completely torn ligaments can regain full continuity with healing
    - ± ligament calcification
    - Pellegrini Stieda: Calcification at proximal attachment of MCL
      - Due to periosteal elevation proximal end of medial femoral condyle ± associated with adductor magnus tendon avulsion
  - Diffusely thickened discontinuous ligament
    - Uncommon sequel
    - Stener lesion: "Yo-yo" sign due to retracted stump of torn ligament lying superficial to adductor aponeurosis
  - Diffusely attenuated ligament
    - Ligament is continuous but reduced in caliber compared to normal ligament
    - Repeated partial tear with fiber resorption
  - Absent ligament
    - No ligament visible
    - Torn fibers undergo gradual attrition or resorption during repair process
  - Ligament laxity with widening of joint space is demonstrated during stress maneuver
- Associated findings
  - Ankle ligament injury: Osteochondral injury talar dome

LIGAMENT INJURY

- MCL tear of knee: Meniscal and cruciate ligament injury
- LCL tear of knee: Posterolateral corner injury

- Chronic stress
  - Some ligaments react to chronic stress by thickening, particularly superomedial fibers of spring ligament

MR Findings

- Complete tear
  - Fiber discontinuity ± hematoma filling gap
- Partial tear
  - Swelling and edema of ligament with periligamentous edema

Imaging Recommendations

- Best imaging tool
  - Ultrasound can assess most ligament injuries
    - MR for associated injuries and for visualizing tears in those ligaments with limited ultrasound access
      - For example, cruciate ligaments of knee
- Protocol advice
  - Assess noninjured contralateral side
  - Align transducer along long axis of ligament
  - Adjust transducer alignment to minimize anisotropy
  - ± stretch ligament to maximize visibility of tear and determine joint laxity

DIFFERENTIAL DIAGNOSIS

Anisotropic Artifact

- Ultrasound beam should be oriented perpendicular to ligament to prevent artifact
- Ligaments are best examined under stretch

Traction Apophysitis

- Apophysitis, epicondylitis, or avulsion fracture of medial humeral condyle (Little League elbow syndrome)
- More common in adolescents

PATHOLOGY

General Features

- Etiology
  - Trauma with undue stretching of ligament
  - Epidemiology
    - Most frequent musculoskeletal injury and injured tissue around joint
    - Ankle sprain is most common cause of injury in college athletes
      - 85% of ankle ligament tears occur laterally, 15% occur medially

Staging, Grading, & Classification

- General
  - Grade 1: Mild partial tear
    - Ligament swollen with no visible ligament discontinuity or avulsion
    - Mild sprain
  - Grade 2: Moderate to severe partial tear
    - Moderate or severe sprain
  - Grade 3: Complete ligament tear or avulsion

Gross Pathologic & Surgical Features

- Inflammatory phase: Bleeding → platelet-rich fibrin clot → release growth factors → repair stimulation
  - Acute inflammation begins immediately after injury and lasts for about 72 hours
- Proliferative phase: Fibroblasts → disorganized scar tissue and proteoglycan filling ligament gap → progressive remodeling
  - Last 4-6 weeks
- Reparative phase: Progressive collagen maturation
  - Last for months to years

Microscopic Features

- Remodeled ligament tissue remains morphologically, biochemically, and functionally inferior to normal ligament
  - Normal ligament (type I ligament 85%); healed ligament is composed of mainly type III collagen
  - Repaired ligament fibers smaller with less cross-linking
    - Ligaments only regain 40-80% of original stiffness and strength but elasticity recovers to about 90%

CLINICAL ISSUES

Presentation

- Most common signs/symptoms
  - Joint pain
  - Pain with apprehension test
- Other signs/symptoms
  - Pain and swelling after traumatic event, instability, early-onset osteoarthritis

Natural History & Prognosis

- Complications
  - Chronic instability → premature osteoarthritis
  - Impingement due to hyperplastic scar tissue
  - Dystropic calcification
  - Contracture due to scar tissue

Treatment

- Conservative
  - RICE: Rest, ice, compression, elevation
  - Controlled exercise regimen
    - Mobilization improves ligament remodeling
  - Prolotherapy (i.e., proliferative therapy)
    - US-guided injection of platelet-rich plasma to injured area
      - Enhances fibroblastic and capillary proliferation
- Surgical
  - Usually for complete tears
  - Ligament fixation to bone

DIAGNOSTIC CHECKLIST

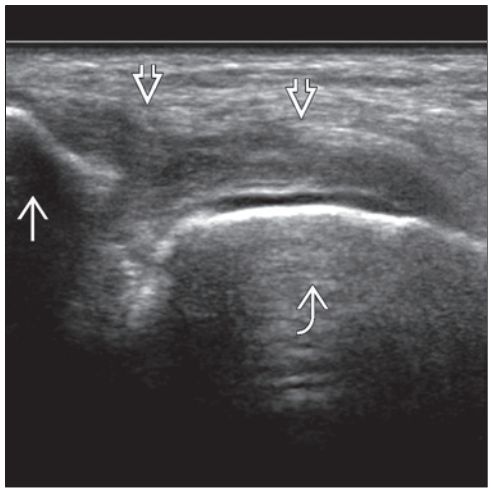
Image Interpretation Pearls

- Examine contralateral noninjured side for comparison
- Perform dynamic assessment with stress maneuver

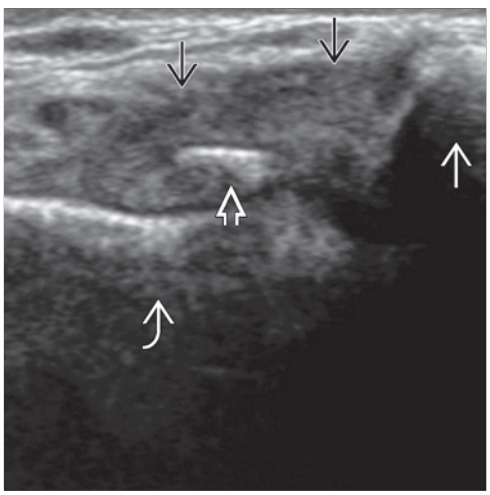
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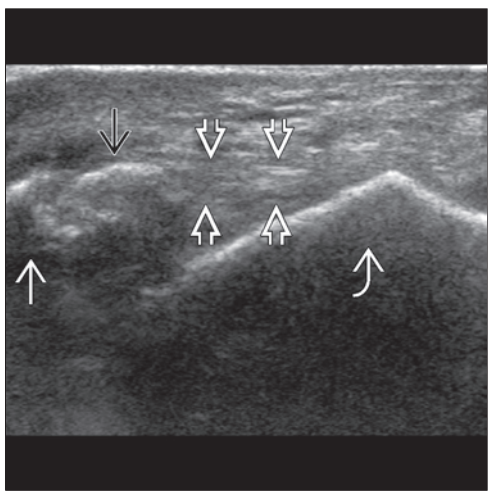
1. Arend CF et al: The role of US in the evaluation of clinically suspected ulnar collateral ligament injuries of the thumb: spectrum of findings and differential diagnosis. Acta Radiol. Epub ahead of print, 2013



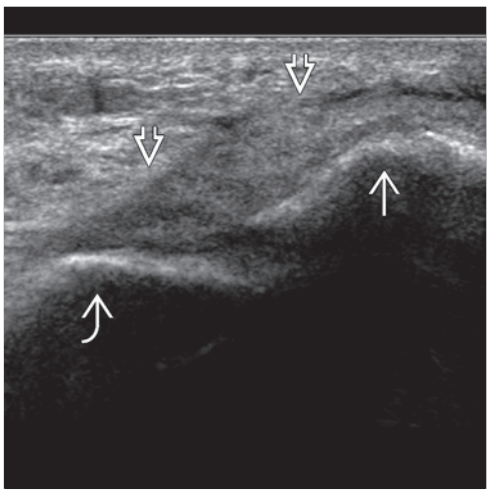


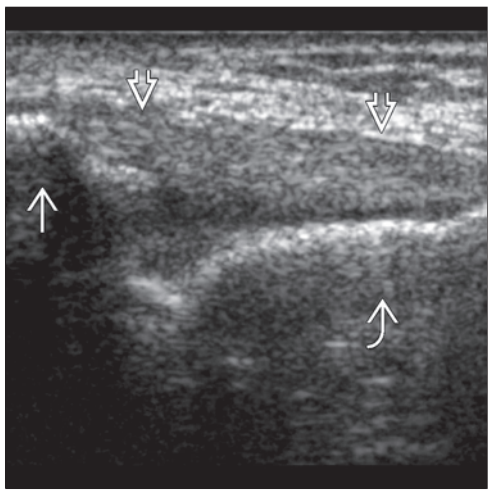
(Left) *Clinical photograph shows lateral ankle swelling with a dependent bruise ⇨ at the inframalleolar region 2 weeks following an inversion injury. Clinically, this is consistent with an ATFL tear.* ***(Right)*** *Longitudinal ultrasound of the same patient shows a severely thickened, hypoechoic ATFL ➔ with fiber continuity between the distal fibula ➔ and talus ➔, compatible with severe (grade 2) partial tear of the ATFL.*





(Left) *Longitudinal ultrasound of the lateral ankle region shows an acute high-grade partial tear of the ATFL ⇨ with a thickened hypoechoic ATFL and loss of the normal fibrillar structure. There is a small avulsed osseous fragment ➔ from the talus ➔. No avulsion is present at the fibular attachment ➔.* ***(Right)*** *Longitudinal ultrasound of the lateral ankle region shows a fracture ➔ of the distal fibula. The intact ATFL ➔, which attaches the fracture fragment ⇨ to the talus ➔, is barely seen.*



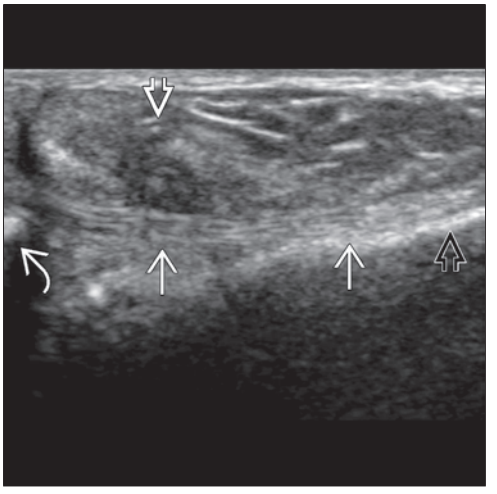


(Left) *Longitudinal ultrasound of the lateral ankle region 4 weeks after inversion injury shows a severely thickened, hypoechoic ATFL ➔ with loss of normal fibrillar pattern between the distal fibula ➔ and talus ➔, compatible with a healing tear.* ***(Right)*** *Longitudinal ultrasound of the lateral ankle in a patient with inversion injury 8 months previously shows a severely thickened, mildly hypoechoic ATFL ➔ between the distal fibula ➔ and the talus ➔, compatible with a largely healed ATFL tear.*

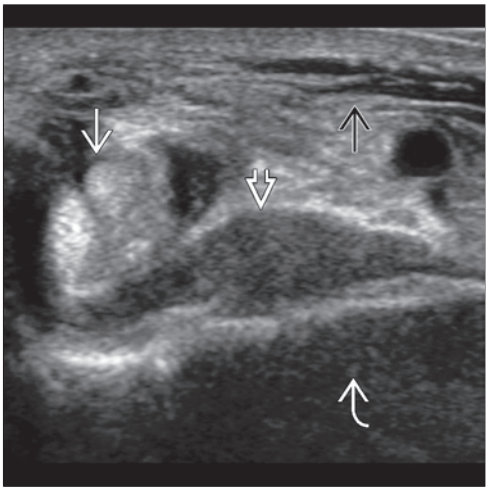
LIGAMENT INJURY

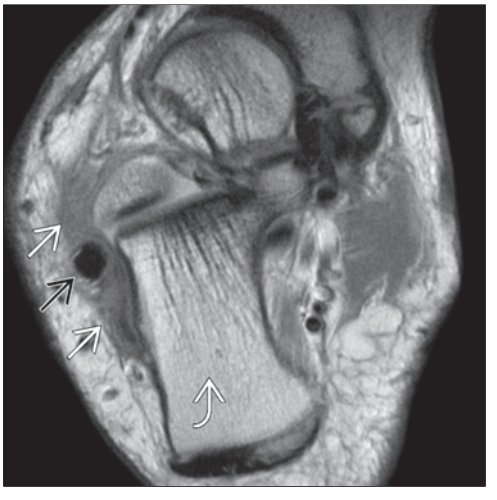
(Left) *Clinical photo shows probe orientation for examining the calcaneofibular ligament (CFL). Ligament visibility can sometimes be improved by dorsiflexing the ankle.* ***(Right)*** *Longitudinal ultrasound of the same patient shows the normal CFL coursing between the fibular tip and the calcaneum deep to the peroneal tendons.*





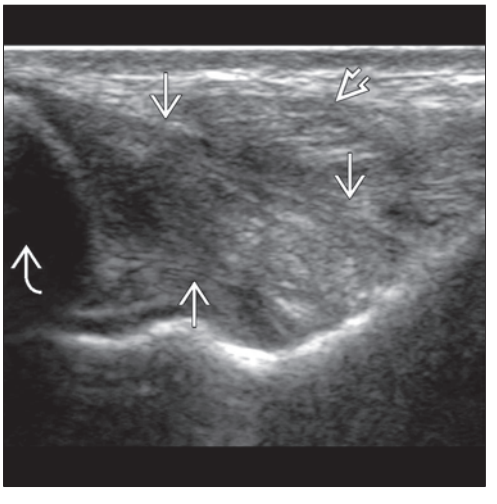
(Left) *Longitudinal ultrasound of the ankle shows a complete (grade 3) CFL tear with a severely thickened, hypoechoic ligament overlying the calcaneum and subcutaneous edema. The peroneal tendons are located close to the calcaneum due to loss of the CFL sling effect.* ***(Right)*** *Axial PD FSE MR of the ankle in a patient with an injury 2 weeks previously shows a severely swollen CFL and the peroneal tendons close to the calcaneum consistent with a complete (grade 3) CFL tear.*

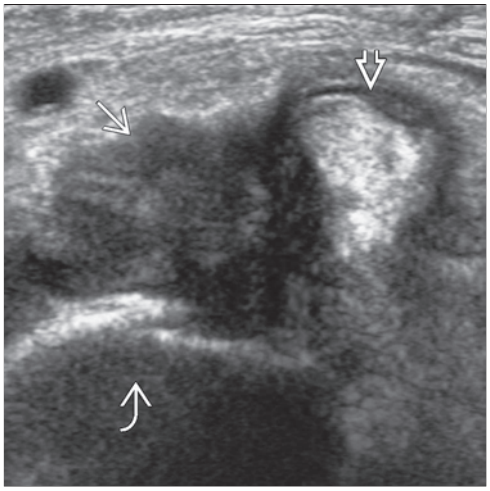


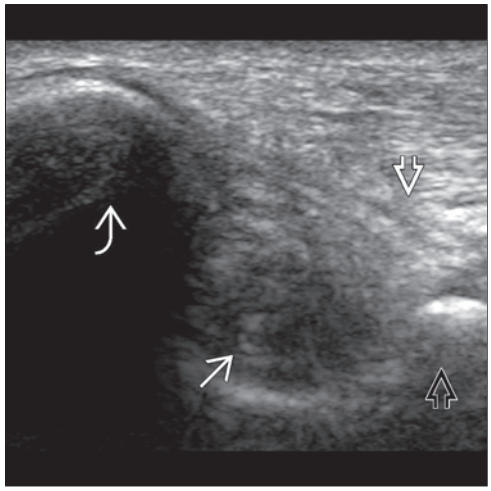


(Left) *Clinical photograph shows the probe orientation for assessing the deltoid ligament. The proximal end of the probe is on the medial malleolus while the distal end sweeps anterior to posterior to view different components of the deltoid ligament.* ***(Right)*** *Longitudinal ultrasound of the medial malleolus shows the normal fan-shaped deltoid ligament deep to the tibialis posterior tendon. The 5 different components of the deltoid ligament are not separable on ultrasound.*

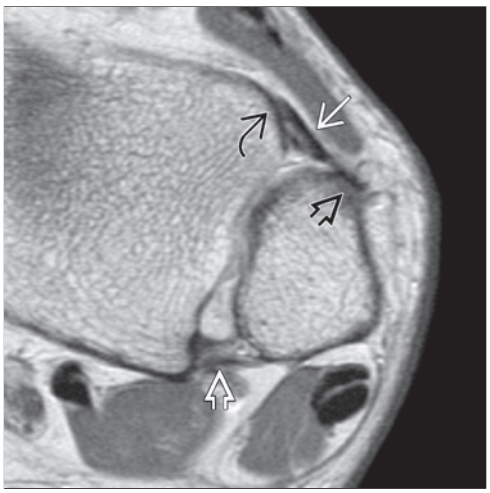






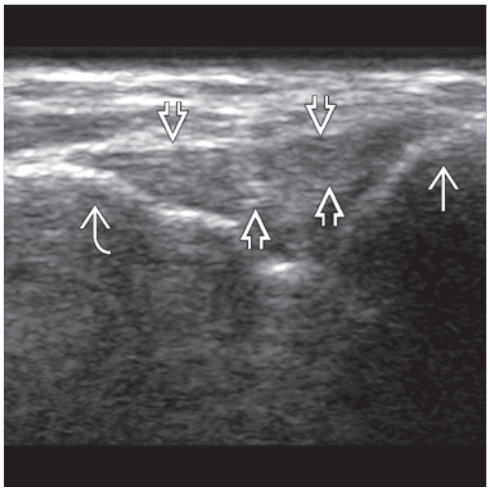


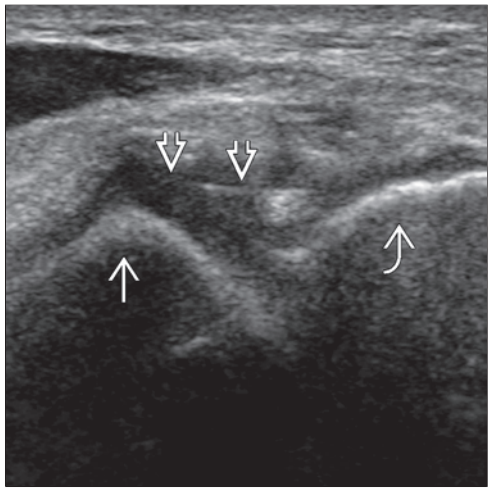
(Left) *Transverse ultrasound of the medial inframalleolar region 1 day after injury shows a severe tear of the deltoid ligament with a hypoechoic, severely thickened deltoid ligament located deep to the tibialis posterior tendon.* ***(Right)*** *Longitudinal ultrasound of the medial ankle 1 week after injury shows a tear of the anterior tibiotalar fibers of the deltoid ligament. The superficial fibers and posterior fibers (not shown) were intact. Note the medial malleolus and talus.*





(Left) *Axial PD FSE MR scan of the tibiofibular articulation shows a normal anterior tibiofibular ligament with intact low signal fibers connecting the anterolateral margin of the tibia to the fibula. The normal posterior tibiofibular ligament with intact low signal fibers is also seen connecting the posterior tibia and fibula.* ***(Right)*** *Clinical photograph shows transducer position for examining the anterior tibiofibular ligament (ATibFL).*

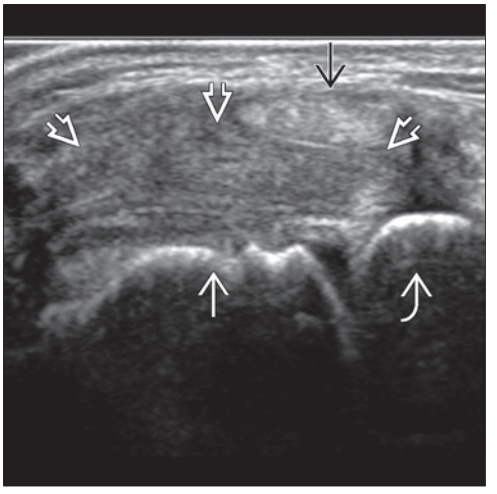




(Left) *Longitudinal ultrasound of a normal subject shows intact ATibFL with normal fibrillar structure coursing between talus and fibula. The ligament is normally wider at the tibial end.* ***(Right)*** *Transverse ultrasound of anterior lower leg shows complete tear of the ATibFL coursing between the tibia and fibula with the gap filling up with fluid. There is no widening of the tibiofibular distance.*

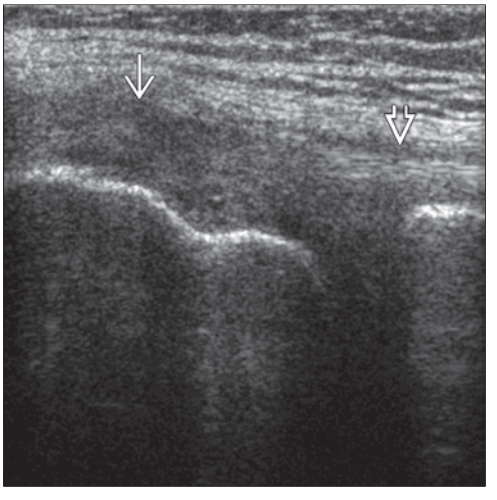
(Left) *Clinical photograph of standing foot shows pes planus with flattening of the medial longitudinal arch.* ***(Right)*** *Longitudinal oblique ultrasound of the medial foot in a patient with pes planus shows severe thickening of the superomedial fibers of the spring ligament. These fibers are located deep to the posterior tibialis tendon and medial to the talar head and navicular bones. The ligament thickens from chronic stress.*



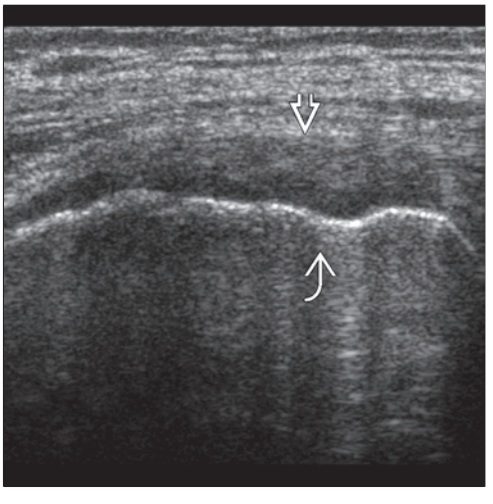


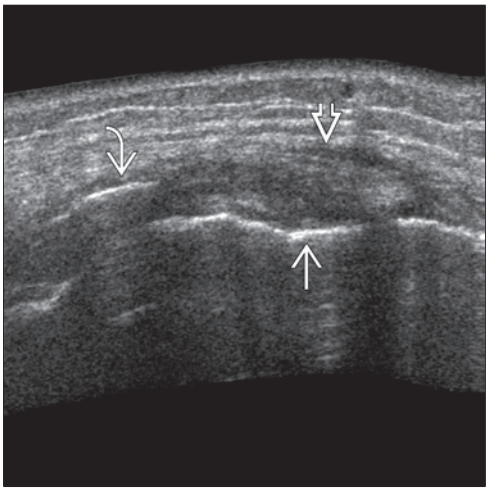
(Left) *Coronal T2WI FS MR shows a severe tear of anterior fibers medial collateral ligament (MCL) with partial periosteal stripping of adductor magnus insertion and partial tear of the superior coronary ligament of the medial meniscus.* ***(Right)*** *Longitudinal ultrasound shows a complete MCL tear at the femoral attachment with swelling and loss of normal fibrillar echotexture. The distal MCL fibers are normal. MCL tears most commonly affect the anterior fibers at the femoral attachment.*

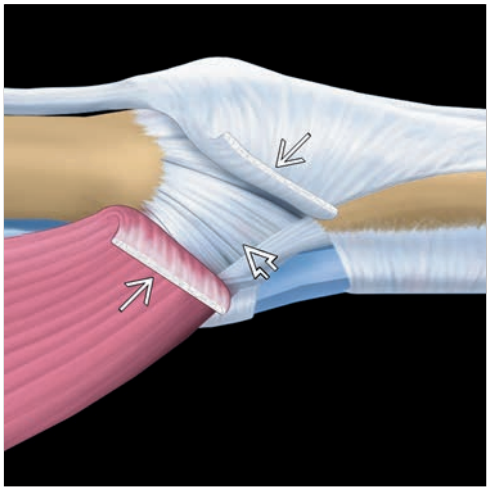


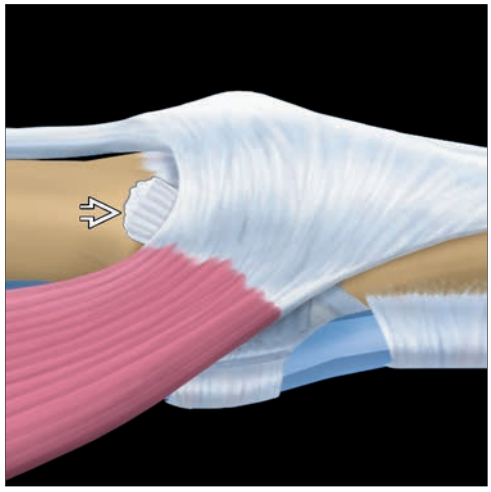


(Left) *Longitudinal ultrasound shows moderate thickening of anterior MCL fibers at the femoral attachment. Fiber structure and continuity can still be resolved consistent with a moderately severe partial tear.* ***(Right)*** *Longitudinal ultrasound shows a Pellegrini-Stieda lesion with linear calcification just proximal to a healing MCL tear at the femoral attachment. This dystrophic calcification is due to either adductor magnus tendon insertional injury or femoral periosteal stripping.*

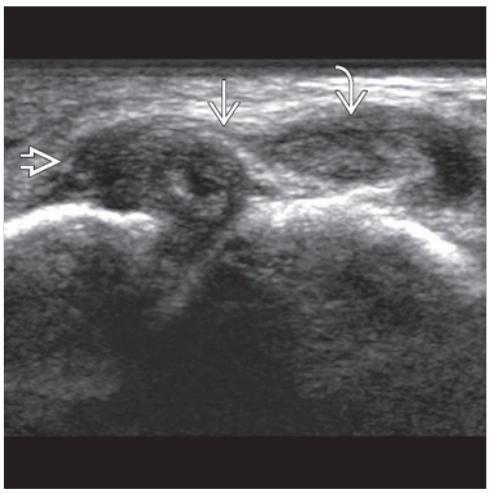






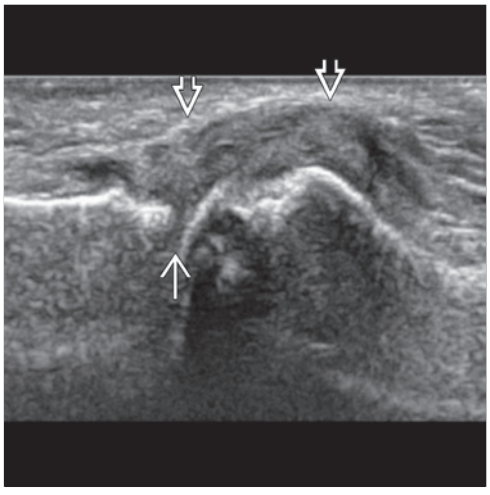


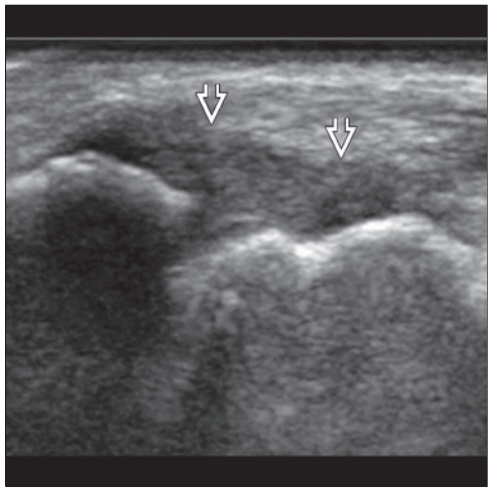
(Left) *Graphic shows the ulnar aspect of the metacarpophalangeal (MCP) joint of the thumb. The image shows a reflected adductor aponeurosis* ➔ *with the ulnar collateral ligament (UCL)* ➔ *beneath.* ***(Right)*** *Graphic shows the ulnar aspect of the MCP joint of the thumb. When a complete tear of the UCL occurs, the proximal end of the ligament may retract back* ➔ *over the adductor aponeurosis. This is referred to as a Stener lesion.*





(Left) *Longitudinal ultrasound of the ulnar aspect of MCP joint of the thumb shows a swollen, irregular, and hypoechoic torn distal end of the UCL* ➔*. The swollen proximal end of the UCL* ➔ *is displaced proximal to the adductor aponeurosis* ➔*.* ***(Right)*** *Clinical intraoperative photograph of the same patient shows a Stener lesion with the torn and retracted UCL* ➔ *located proximal and slightly superficial to the adductor aponeurosis* ➔*.*





(Left) *Longitudinal ultrasound of the ulnar side of the MCP joint* ➔ *of the thumb shows a severely thickened hypoechoic UCL* ➔*. No discernible continuous fibers are seen in this thickened ligament, which are compatible with high-grade partial tear.* ***(Right)*** *Longitudinal ultrasound of the MCP joint of the thumb shows a severely thickened hypoechoic radial collateral ligament* ➔ *compatible with a high-grade partial tear.*

BONE FRACTURE

Key Facts

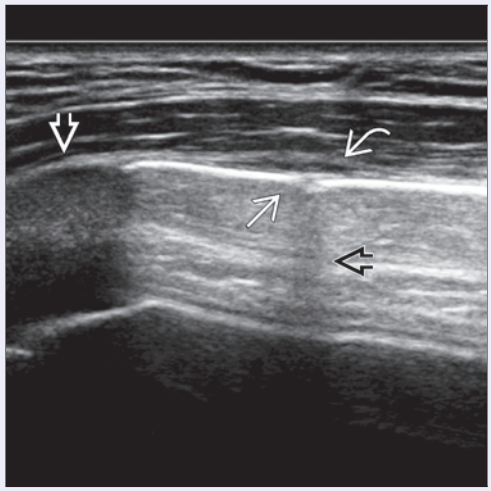
Terminology

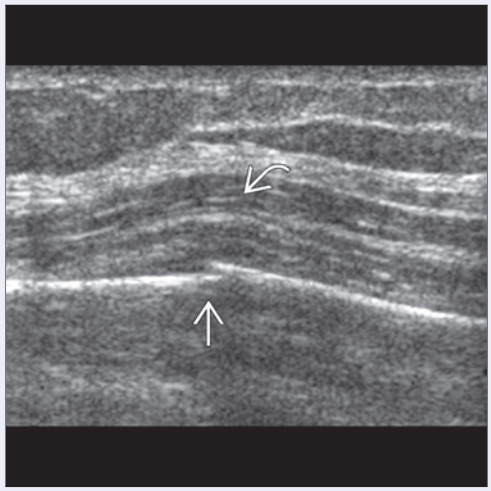
- Fracture (Fx): Traumatic discontinuity of bone usually involving both cortical and trabecular bone
- Stress Fx: Fx occurring in normal bone due to excessive repetitive submaximal loading
- Pathological Fx: Fx occurring in focally weakened bone subjected to normal loading

Imaging

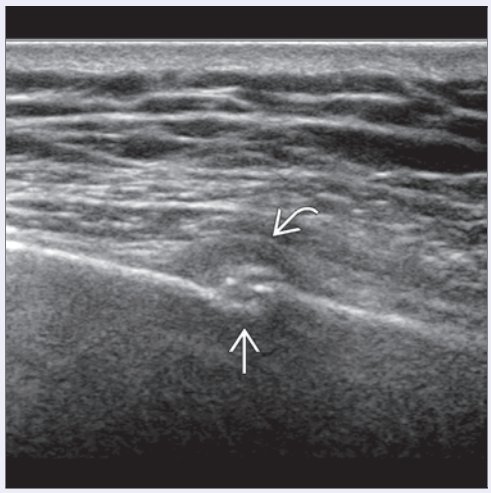
- Standard radiographs will not show
  - 85% of rib Fxs, 50% of nasal bone Fxs, 15% of scaphoid Fxs
  - 25% of pediatric elbow Fxs, 100% of chondral Fxs
- Fracture
  - Focal cortical disruption with adjacent soft tissue edema, hematoma, or callus
  - ± reverberation artifact at Fx line
  - Fx edge resorption occurs with hypoechoic osteoid deposition across Fx line
  - → progressive callus mineralization
- Stress Fx
  - Thickened hyperechoic periosteum at symptomatic site
  - Visible on ultrasound before radiographs
  - Hyperemia of thickened periosteal rim on color Doppler imaging
- Pathological Fx
  - Often wider Fx line ± cortical irregularity extending beyond Fx margins
  - ± visible tumor protruding from Fx gap
- Chondral Fx
  - Focal disruption of hypoechoic cartilage
  - ± juxtachondral soft tissue edema or hematoma

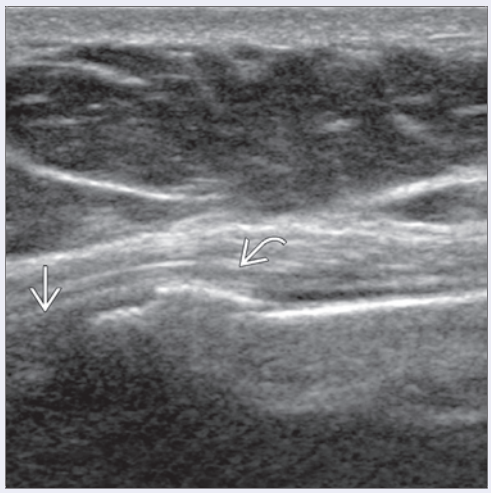
(Left) *Transverse ultrasound shows an acute undisplaced fracture in the anterior aspect of the rib with focal discontinuity of the cortex, minimal soft tissue swelling, and posterior reverberation ("Chimney phenomenon"). Note the costochondral junction and hypoechoic costal cartilage radiograph was normal.* ***(Right)*** *Transverse ultrasound shows a mildly angulated acute fracture in the anterior axillary line with mild overlying soft tissue swelling. Radiograph was normal.*





(Left) *Transverse ultrasound shows a partially healing fracture in the midaxillary line. There is hypoechoic callus surrounding the fracture with echogenic mineralization more deeply. This stage of fracture healing may no longer be painful.* ***(Right)*** *Transverse ultrasound shows a healing fracture at the anterior aspect of rib close to the costochondral junction. Most of the callus has mineralized. There is no soft tissue swelling.*





BONE FRACTURE

TERMINOLOGY

Definitions

- Fracture (Fx): Traumatic discontinuity of bone usually involving both cortical and trabecular bone
- Trabecular microfracture: Fx limited to trabecular component of bone without clear Fx line
  - Diffuse bone marrow edema on MR imaging but no discrete Fx line
- Stress Fx: Fx occurring in normal bone due to excessive repetitive submaximal loading
- Stress reaction of bone: Trabecular microfracture occurring in normal bone due to repetitive excessive submaximal loading
- Insufficiency Fx: Fx occurring in diffusely weakened bone subjected to normal loading
  - Usually due to osteoporosis; other causes include renal osteodystrophy and chronic bisphosphonate therapy
- Pathological Fx: Fx occurring in focally weakened bone subjected to normal loading
  - Usually due to metastatic infiltration or primary bone tumor; infection is another cause

IMAGING

General Features

- Best diagnostic clue
  - Focal disruption of bone cortex with juxtacortical soft tissue edema/hemorrhage ± callus formation
- Location
  - Most common in ribs, distal radius, scaphoid, metacarpals, phalanges, metacarpals, nasal bones, skull, and vertebral bodies

Radiographic Findings

- Standard method of Fx assessment
  - Shows majority of Fx to good effect
  - Limited depiction of some Fxs
  - Standard radiographs will not show
    - 85% of rib Fxs, 50% of nasal bone Fxs, 15% of scaphoid Fxs
    - 25% of pediatric elbow Fxs, 100% of chondral Fxs
    - < 5% of proximal femoral and distal radial Fxs in osteopenic patients

MR Findings

- Gold standard for fracture detection
  - Detects both cortical and trabecular component of Fx as well as stress reaction with high sensitivity, specificity, and negative predictive value

Ultrasonographic Findings

- Fx
  - Focal cortical disruption with adjacent soft tissue edema, hematoma, or callus
    - ± reverberation artifact ("chimney phenomenon") or shadowing artifact at Fx site
    - Effusion, hemarthrosis, or lipohemarthrosis if intracapsular surface extension is present
  - Later, Fx edge resorption occurs with hypoechoic osteoid deposition across Fx line
  - → progressive callus mineralization
  - → complete callus mineralization → smooth bump on cortical contour
- Stress Fx
  - Thickened rim of hyperechoic periosteum at symptomatic site
    - Visible on ultrasound before radiographs
  - Hyperemia of thickened periosteum on color Doppler imaging
  - → progressive increasing echogenicity of periosteal thickening due to increasing bone deposition
- Pathological Fx
  - Often wider Fx line ± cortical irregularity extending beyond Fx margins
  - ± visible tumor protruding from Fx gap
- Insufficiency Fx
  - Periosteal thickening and hyperemia with adjacent soft tissue edema
  - ± focal cortical irregularity or disruption
  - Overall sensitivity of ultrasound for early insufficiency Fx is low
    - Propagates from trabecular bone and is therefore not visible on ultrasound at early stage
- Chondral Fx
  - Focal disruption of hypoechoic cartilage
  - ± juxtachondral soft tissue edema or hematoma
    - Heals by fibrocartilaginous repair
    - No callus formation

Imaging Recommendations

- Best imaging tool
  - Radiography ± ultrasound for selected Fx detection
  - Increasingly, ultrasound is advocated as best initial investigation for suspected rib, sternal, nasal bone, and skull Fxs
  - With suitable training, ultrasound can detect or exclude Fxs in these areas with high (> 90%) sensitivity and specificity
    - Ultrasound can be used as standalone investigation or as supplement to radiography
  - Ultrasound assessment of Fx is severely limited in
    - Retroscapular area of rib cage and spine
    - Intraarticular areas, carpus or tarsus
    - Reduced transducer access due to open wound, severe abrasion, or external fixation
    - Gas or severe trauma to soft tissues impairing acoustic transmission
    - Assessment of any trabecular fracture
    - Unconscious or uncooperative patient
      - Cannot localize painful area
    - Complex Fx as overall Fx perception is limited
  - In addition to fracture detection, ultrasound can also
    - Check alignment of Fx post reduction
      - More time efficient compared to repeating radiographs
    - Guide hematoma local anesthetic block
      - Significantly ↓ need for systemic analgesics in immediate post-Fx period
    - Check for neurovascular bundle injury in at-risk Fx
      - For example, displaced pediatric supracondylar Fx (Garland type III)
    - ~ 25% have compromised brachial artery flow
    - Due to kinking, spasm, thrombosis ± laceration of brachial artery
- Protocol advice
  - Focus examination on area of maximum pain or tenderness

BONE FRACTURE

- Align transducer with long axis of bone
- Check for cortical as well as juxtacortical signs of Fx
- Determine location, displacement, angulation, comminution, and alignment of Fx as well as integrity of adjacent cortex
  - Check juxtacortical soft tissues for edema, hematoma, presence and maturity of callus
- ± finger-palpation test to ensure ultrasound abnormality corresponds to point of maximum tenderness
- Check for Fx-related complications
- For rib Fx
  - Usually examine patient in decubitus position but also in supine or prone positions depending on where painful site is located
  - Ask patient to point to most painful area and start examination at this site
  - Align transducer along long axis of rib
  - Then examine this rib from the costosternal junction to the costovertebral junction
  - Repeat procedure for all ribs in painful area
  - If rib Fx is detected, note site of Fx on skin with bleb of ultrasound gel
    - Place transducer in oblique longitudinal plane over 12th rib, and count ribs backwards towards bleb of gel
    - In addition to rib number, report whether rib Fx is located in midscapular line; posterior, mid-, or anterior axillary line; or midclavicular line
  - Only weak correlation exists between degree of rib fracture displacement/alignment and time to clinical healing
  - Check for pneumothorax
    - Align transducer within intercostal space parallel to ribs at the least dependent portion of affected hemithorax
    - Look for absence of "gliding" sign (lung gliding at pleural interface on real-time scanning)
    - Look for absence of moving "comet tail" artifacts at lung surface (on real-time scanning)
    - Ultrasound is as sensitive as radiography for pneumothorax detection
  - Check for pleural effusion or hemothorax at most dependent portion of affected hemithorax
  - ± brachial plexus injury in upper rib Fx
    - C7 transverse processes lacks anterior tubercle
    - C4-C7 roots are reliably seen on ultrasound, but visibly of C8 and T1 roots is limited
    - Upper rib Fx is uncommon and associated with severe trauma
- For nasal bone Fx
  - Examine longitudinal and transverse planes in midline area and oblique longitudinal scans of lateral walls of nasal bone
  - Determine degree of Fx displacement and whether compression (telescoping) of nasal bones is present
    - If Fx is displaced or compressed, CT is helpful to further evaluate

DIFFERENTIAL DIAGNOSIS

Physiological Cortical Irregularity or Physis
- No adjacent soft tissue edema, hematoma, or callus

Bone-Allograft or Bone-Prosthetic Junction
- No adjacent soft tissue edema, hematoma, or callus

PATHOLOGY

Staging, Grading, & Classification
- Hematoma at Fx site with inflammatory response
  - Production and release of proinflammatory cytokines
  - Peaks at 24 hours; completes after 7 days
  - Local and systemic recruitment of mesenchymal stem cells
  - Fibrin-rich granulation tissue forms and replaces hematoma in and around Fx site
- Elevation and stimulation of periosteum → intramembranous ossification at subperiosteal site (hard callus) → bridging woven bone
- Endochondral formation within granulation tissue (soft callus) → progressive endochondral ossification of soft callus
- Bone remodeling → original lamellar structure and external shape

CLINICAL ISSUES

Presentation
- Most common signs/symptoms
  - Acute localized pain and tenderness after trauma
- Other signs/symptoms
  - Swelling, hematoma, ecchymosis, and limitation of movement
  - Stress Fx: Pain induced by exercise & relieved by rest
    - Pain increases with increasing intensity of exercise

Natural History & Prognosis
- Severe pain for ~ 1 week; symptom-free in 6-8 weeks

Treatment
- Initially rest, ice, compression, and elevation (RICE)
- ± Fx reduction ± cast immobilization
- Functional casting or brace
- External or internal metallic fixation

DIAGNOSTIC CHECKLIST

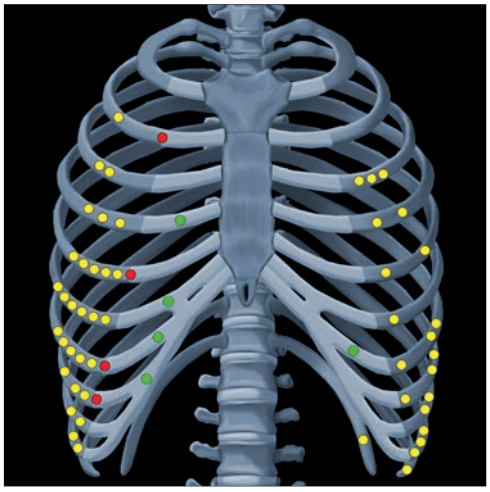
Consider
- Using ultrasound to detect fracture in those known sites where radiography is limited

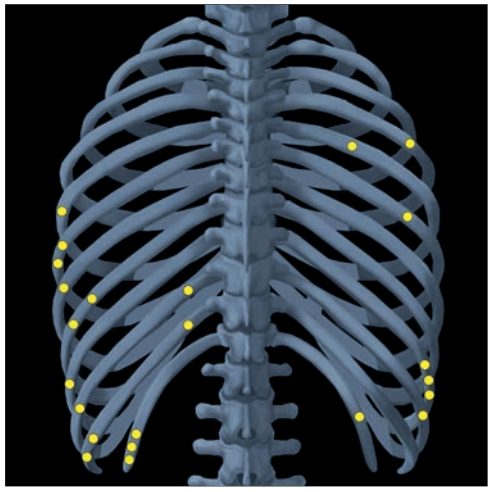
Image Interpretation Pearls
- Localized cortical discontinuity at tender spot with adjacent soft tissue injury or reparative change

SELECTED REFERENCES

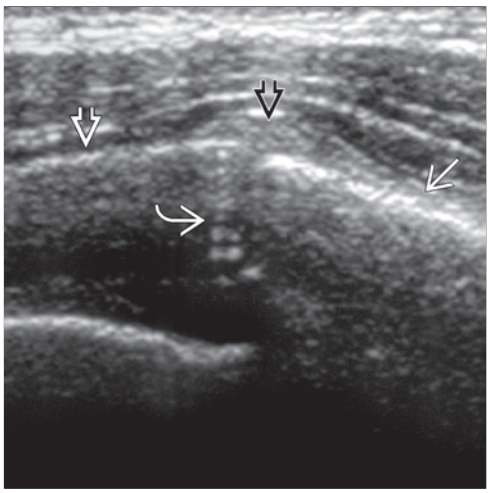
1. Lou YT et al: Conductor-assisted nasal sonography: an innovative technique for rapid and accurate detection of nasal bone fracture. J Trauma Acute Care Surg. 72(1):306-11, 2012

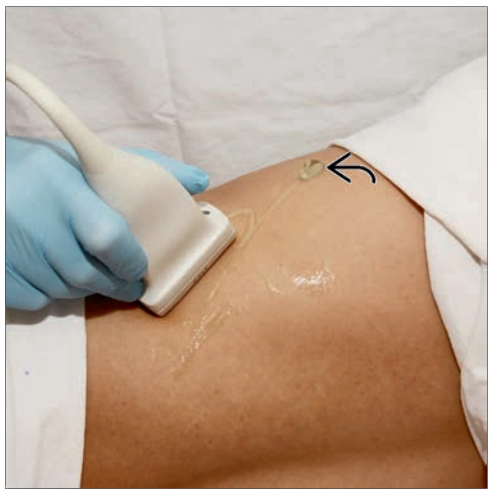
BONE FRACTURE





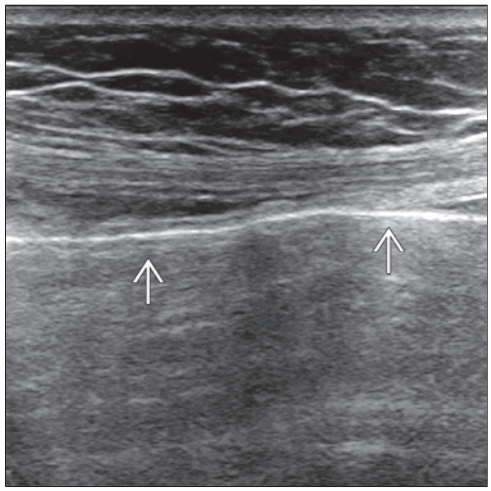
(Left) *Graphic of the anterior chest wall shows the common locations of rib fractures (yellow dots), costochondral junction fractures (red dots), and costal cartilage fractures (green dots).* ***(Right)*** *Graphic of the posterior chest wall shows the common locations of rib fractures (yellow dots). Note that most chest wall fractures occur anteriorly (preferentially affecting the lower ribs) and are more common on the right side anteriorly and on the left side posteriorly.*





(Left) *Transverse ultrasound shows an acute undisplaced costochondral junction fracture with mild soft tissue swelling anterior to the junction between the osseous and chondral portions of the rib. Note reverberation artifact at the fracture site ("chimney phenomenon").* ***(Right)*** *Photograph shows how to name which rib is fractured. Mark the fracture site with gel. Place the transducer transversely over the 12th rib, and move it upwards to the fracture site while counting down the ribs as the transducer passes over them.*

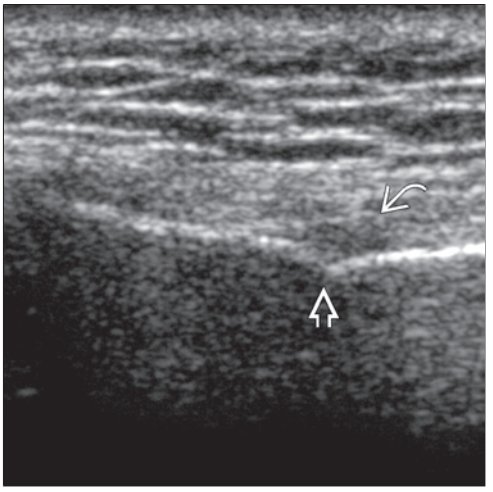


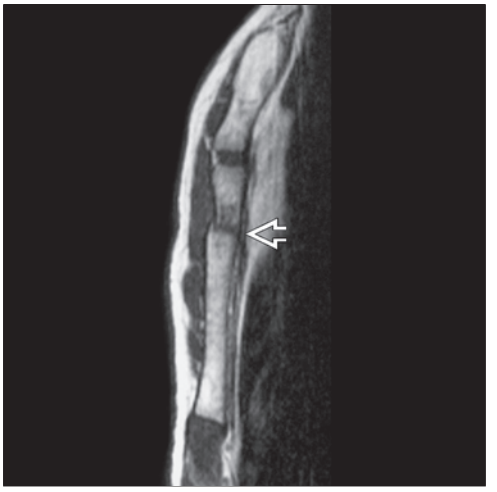


(Left) *Transverse ultrasound of a normal lung while scanning in intercostal space shows normal, thick, irregular echogenic pleural interface with reverberation artifacts, which moves "to and fro" on real-time grayscale imaging.* ***(Right)*** *Transverse ultrasound shows pneumothorax with a thin, sharp echogenic line on the parietal pleural surface and absence of reverberation artifact. On real-time imaging, no pleural interface "to and fro" movement is present, enabling clear recognition of pneumothorax.*

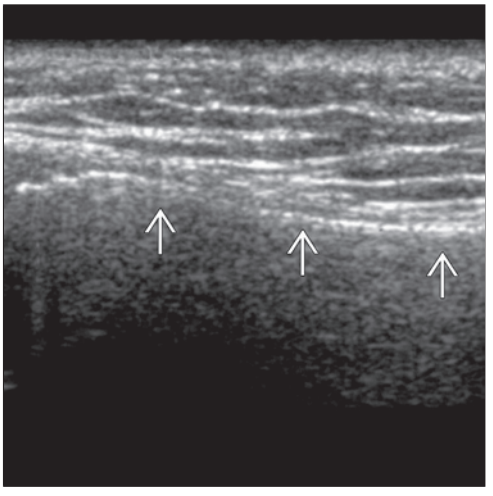
BONE FRACTURE

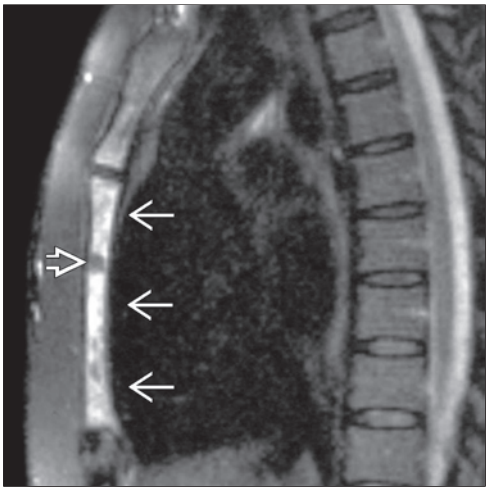
(Left) *Longitudinal ultrasound in a patient with anterior chest pain following a fall shows an angulated fracture of the sternal body with mild associated soft tissue swelling. Radiograph was normal.* ***(Right)*** *Sagittal T1WI MR confirms a mildly angulated transverse fracture of the sternal body. A high percentage of sternal fractures are not visible on radiographs. When compared with MR, ultrasound will allow correct identification or exclusion of most sternal fractures.*



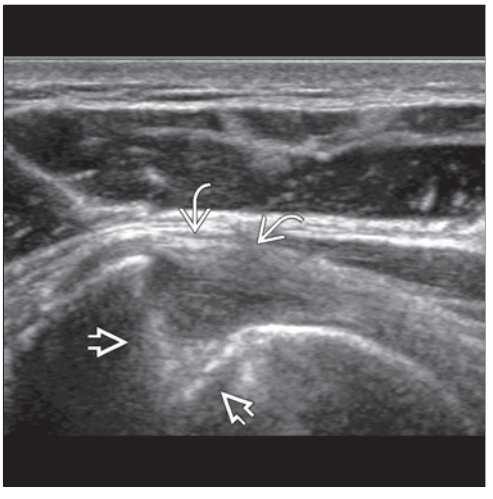


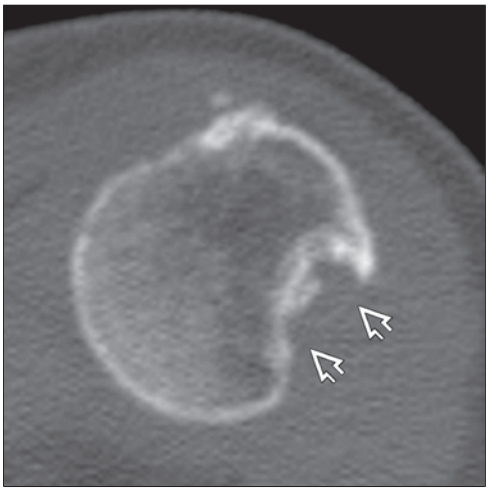
(Left) *Longitudinal ultrasound in a patient with clinically suspected sternal fracture shows no evidence of fracture with an intact anterior cortical margin.* ***(Right)*** *Longitudinal T2WI FS MR shows diffuse marrow edema of the sternal body but no sternal fracture. The localized hypointense area within the sternal marrow is most likely due to a hematopoietic cell rest.*

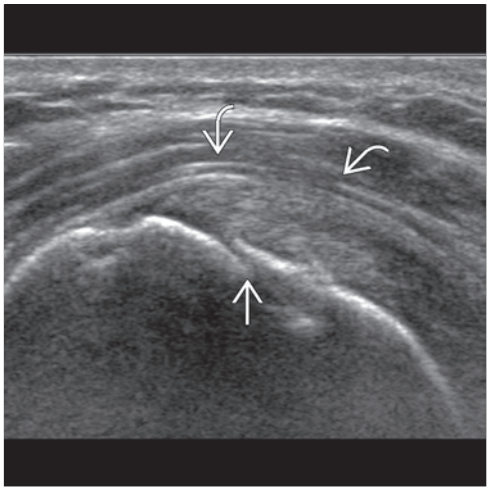




(Left) *Longitudinal ultrasound shows an angulated Hill-Sach compression fracture at the posterosuperior aspect of the humeral head secondary to recent anterior dislocation. Cortical indention, occasionally due to posterosuperior impingement, is common at this location and difficult to distinguish from a Hill-Sach fracture in the setting of anterior dislocation. There is moderate swelling of the overlying infraspinatus tendon.* ***(Right)*** *Axial CT shows a large angulated Hill-Sachs deformity.*



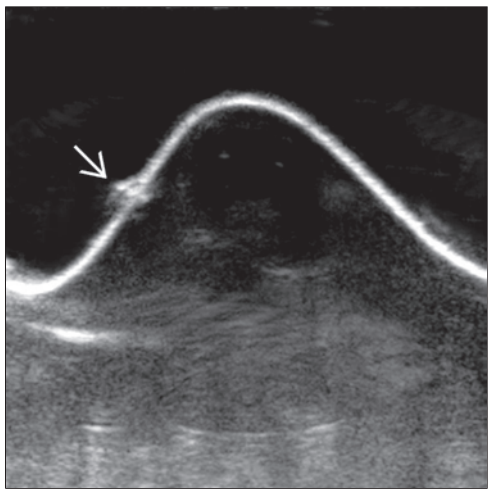




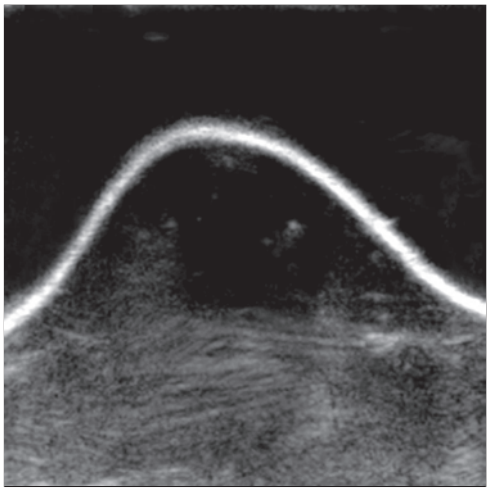


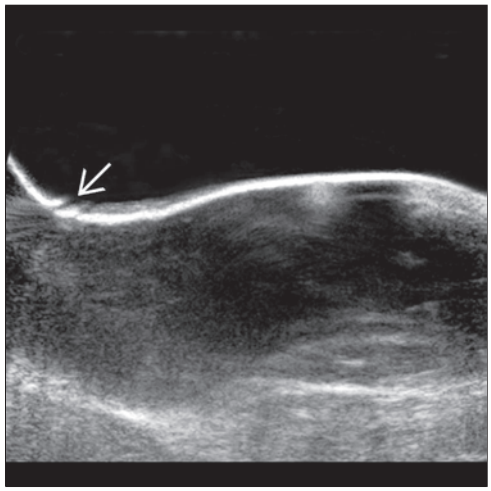
(Left) *Radiograph in a patient with shoulder pain following a fall was negative. Transverse ultrasound shows an undisplaced fracture of the greater tuberosity* ➔. *The overlying supraspinatus tendon* ➔ *is normal.* ***(Right)*** *Longitudinal ultrasound of the same shoulder shows another view of the tuberosity fracture with a reverberation artifact* ➔ *deep to the cortical defect* ➔. *Radiographically occult fracture of the greater tuberosity is not uncommon in patients following direct shoulder trauma.*





(Left) *Photograph shows how a surgical glove filled with fluid* ➔ *can be used as a good standoff to examine for suspected nasal bones fracture.* ***(Right)*** *Transverse ultrasound of the nose of a normal subject shows the normal smooth contour of the nasal bones. The small echogenic area on the nasal side wall* ➔ *is an artifact caused by entrapped air. Up to 50% of nasal bone fractures are radiographically occult, whereas the sensitivity/specificity of ultrasound for nasal fracture detection is > 90%.*

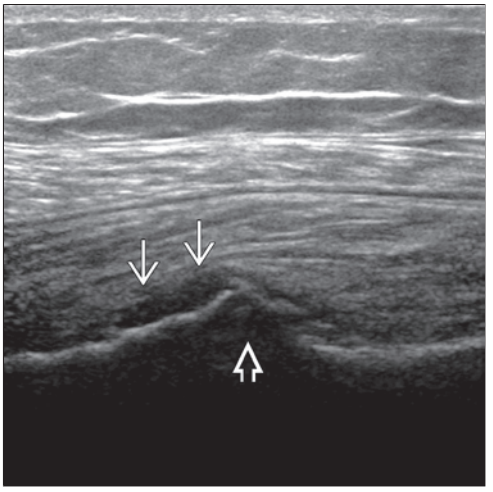


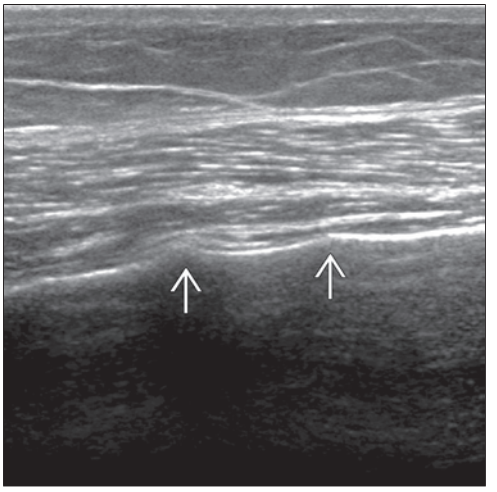


(Left) *Transverse ultrasound of the same patient's nose following readjustment of the standoff shows no artifact.* ***(Right)*** *Longitudinal ultrasound of the midsagittal section shows the normal smooth contour of the nasal bones. The nasofrontal suture* ➔ *is clearly seen. Standard ultrasound protocol of the nose should include longitudinal midline, longitudinal lateral (along nasal side walls), and transverse views.*

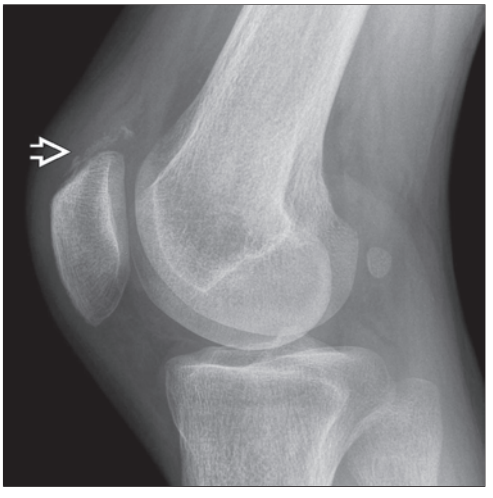
BONE FRACTURE

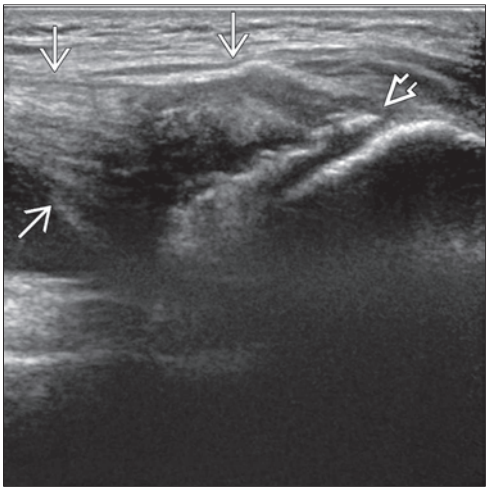
(Left) *Longitudinal ultrasound of the lateral aspect of the proximal femoral shaft in an elderly patient with thigh pain shows an osseous spike with a thin hypoechoic rim due to unossified callus. This is consistent with an insufficiency fracture, associated with chronic bisphosphonate therapy and atypical subtrochanteric fracture.* ***(Right)*** *Longitudinal ultrasound of an elderly patient shows 2 similar, though smaller, fractures. These fractures should be further assessed by radiography ± CT.*



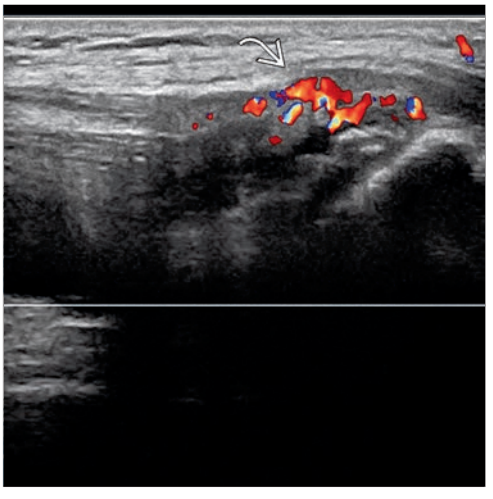


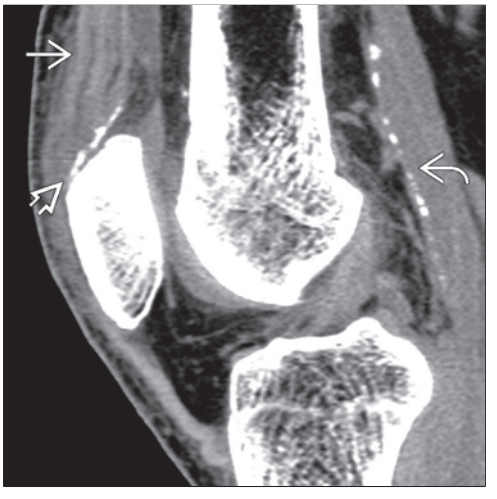
(Left) *Lateral knee radiograph in a young patient with chronic renal failure and renal osteodystrophy shows a faint periosteal avulsion fracture from the superior pole of the patella. There is radiographic evidence of hyperparathyroidism.* ***(Right)*** *Longitudinal ultrasound of the same patient shows the quadriceps tendon attached to the thin periosteal sleeve avulsion fracture. This type of fracture is more common in children and in patients with metabolic bone disease.*

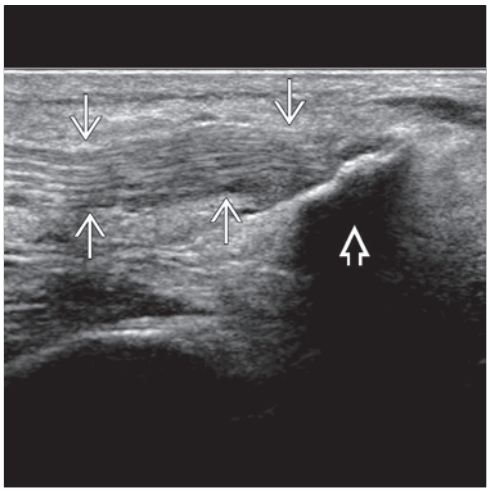


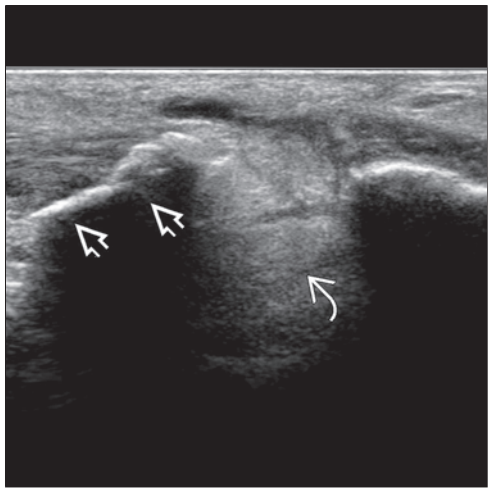


(Left) *Longitudinal color Doppler ultrasound of the same patient as previous image shows moderate hyperemia of the fracture site.* ***(Right)*** *Sagittal reformat CT image of the same patient shows a periosteal sleeve fracture with the quadriceps tendon attached avulsed from the superior pole of the patella. This type of fracture can also occur at the inferior pole of the patella. Note arterial calcification in this young patient due to chronic renal failure.*







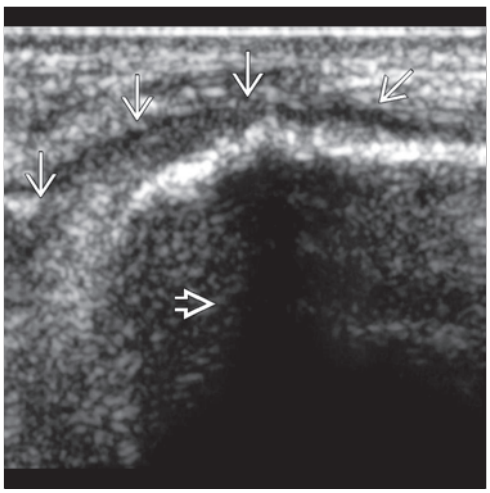


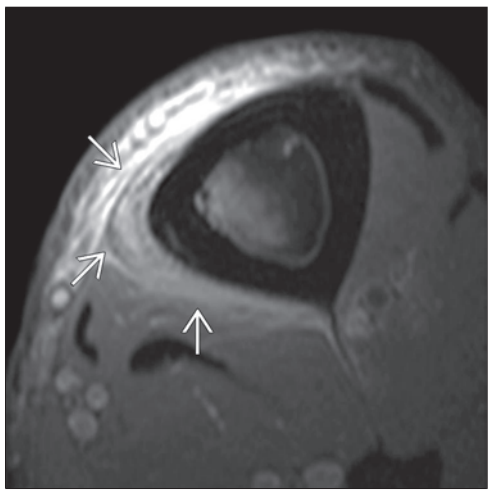
(Left) *Longitudinal ultrasound in a middle-aged patient with heel pain shows an avulsion fracture* ➪ *in the posterosuperior aspect of the calcaneum with an attached Achilles tendon* ➔. ***(Right)*** *More distal longitudinal ultrasound of the same patient shows the unusually large avulsion fracture* ➪. *Most calcaneal avulsion fractures involve only a thin sliver of bone. Note the echogenic hematoma within the fracture gap* ➪.





(Left) *Lateral radiograph subsequently obtained in the same patient allows the thickness of the fracture fragment* ➪ *to be better appreciated. The fragment has displaced more than on the earlier ultrasound examination. The calcaneal bone defect* ➪ *is readily apparent.* ***(Right)*** *Lateral radiograph in same patient six weeks following fracture reduction and screw fixation shows good healing* ➪. *No other imaging was necessary other than ultrasound and radiography.*



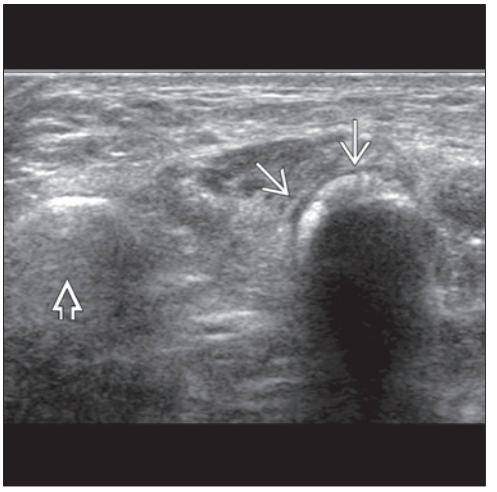


(Left) *Transverse ultrasound of the midtibial shaft* ➪ *in an athlete shows moderate periosteal thickening* ➪ *posteromedially. Radiograph was negative. Ultrasound can reveal bony stress injury at an earlier stage than radiography.* ***(Right)*** *Axial T2WI FS MR in a different patient shows a hyperintense rim* ➔ *of thickened fluid-rich periosteum extending around the posteromedial aspect of the tibia. The underlying cortical thickening as well as cortical and marrow edema would not be apparent on ultrasound.*

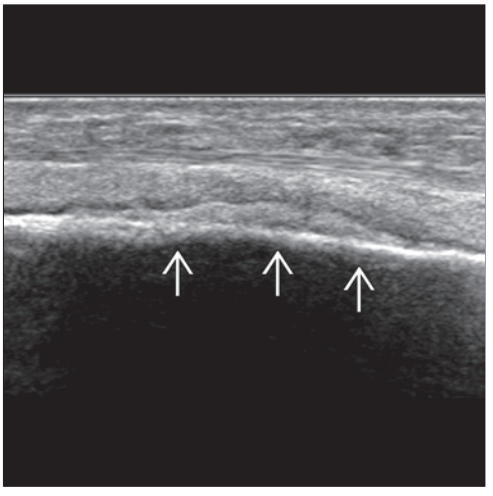
BONE FRACTURE

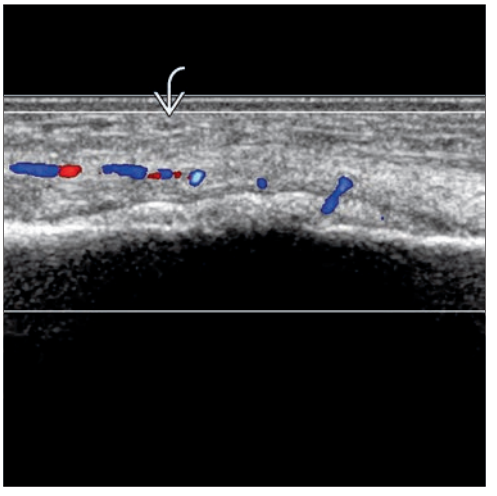
(Left) *Photograph from a young female with bilateral foot pain and swelling for 2 months following commencement of an exercise regimen shows that the left foot is moderately swollen. Pain was initially more severe on the right side though now is more severe on the left side.* ***(Right)*** *Transverse ultrasound shows an echogenic rim of thickened periosteum around the left 2nd metatarsal shaft. This is consistent with a stress fracture. The normal 3rd metatarsal shaft is also shown for comparison.*





(Left) *Longitudinal ultrasound of the left 2nd metatarsal shaft of the same patient shows a focally thickened echogenic periosteum. Normal nonthickened periosteum is not visible on ultrasound.* ***(Right)*** *Longitudinal color Doppler ultrasound of the same patient shows mild hyperemia around the thickened periosteum. Ultrasound is more sensitive than radiography at detecting early metatarsal stress fracture.*

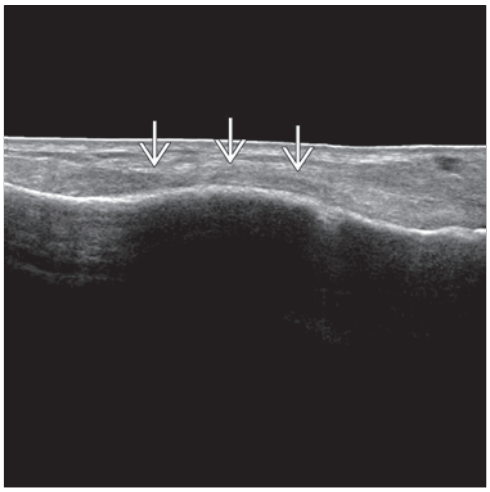




(Left) *Dorsoplantar radiograph of the left foot in the same patient as previous image performed at the same time as ultrasound examination shows no radiographic evidence of stress fracture, particularly in the 2nd metatarsal shaft.* ***(Right)*** *Dorsoplantar radiograph of the same foot 2 months later shows unequivocal focal cortical thickening in the 2nd metatarsal shaft, consistent with a stress fracture. No other imaging was obtained.*

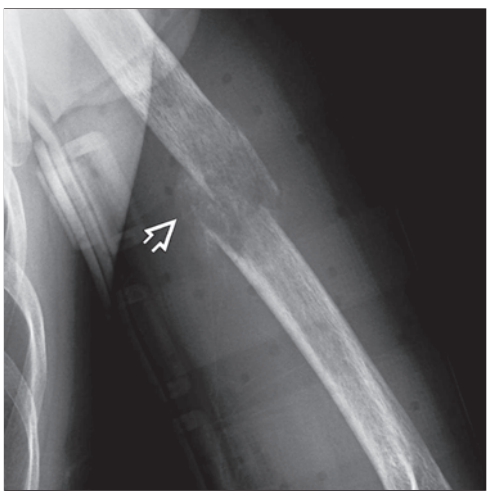


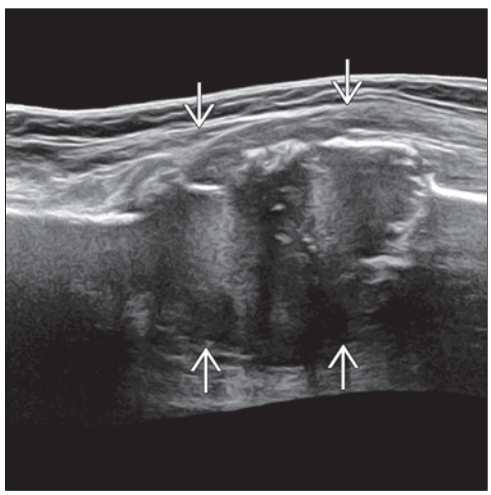




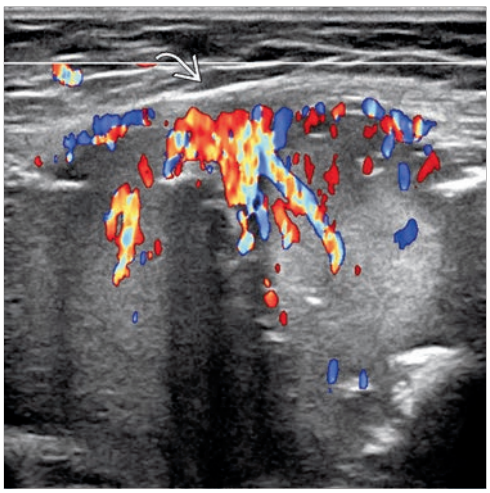


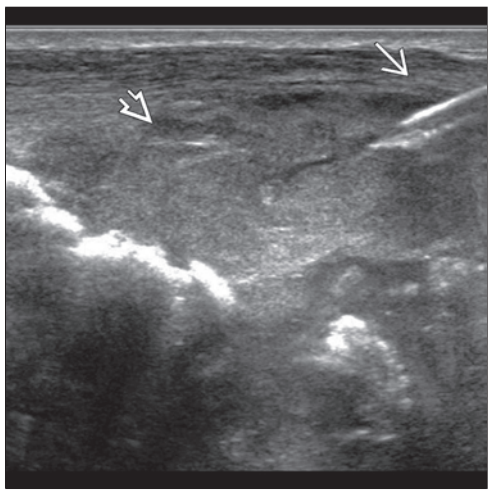
(Left) *Extended field-of-view ultrasound shows smooth expansion ➔ of the 2nd metatarsal midshaft due to a healed stress fracture. No periosteal thickening is present. Similar changes were present along the 3rd metatarsal shaft.* ***(Right)*** *Dorsoplantar oblique radiograph of the same patient shows healed stress fractures ➔ of the 2nd and 3rd metatarsal shafts. Ultrasound is not generally indicated in radiographically visible chronic stress fractures.*



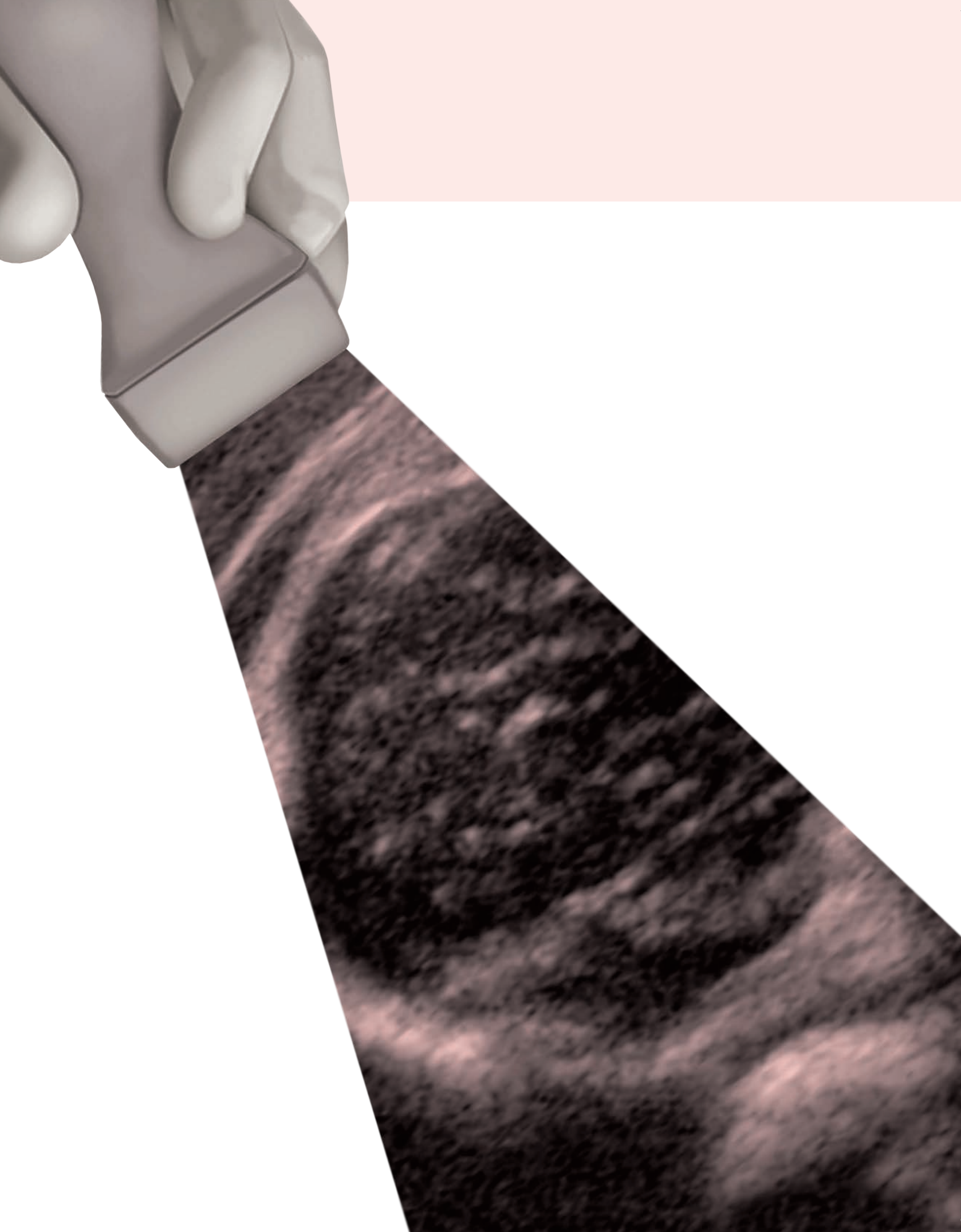


(Left) *Frontal radiograph shows a mildly displaced transverse pathological fracture ➔ of the midhumeral shaft in a patient with no known primary tumor.* ***(Right)*** *Extended field-of-view ultrasound in the same patient shows a large pathological-type fracture in the midshaft of the humerus with irregular cortical osteolysis and mild osseous expansion ➔.*





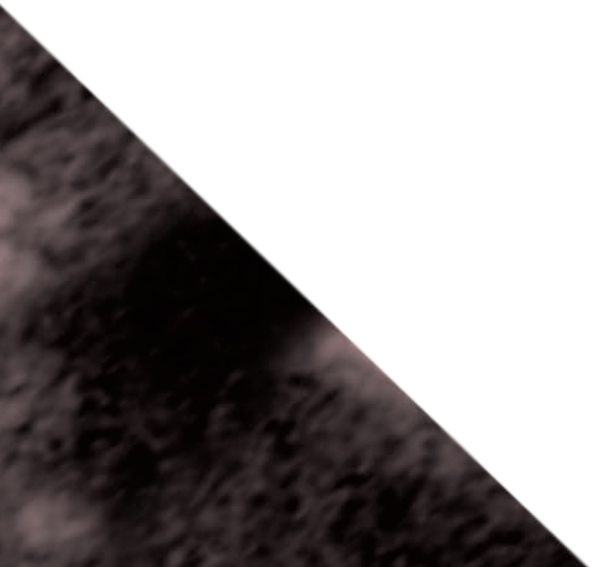
(Left) *Transverse color Doppler ultrasound of the same tumor as previous image shows marked hyperemia ➔, confirming the presence of a viable tumor rather than a hematoma.* ***(Right)*** *Longitudinal oblique ultrasound shows the same extraosseous tumor component ➔ during biopsy ➔. Biopsy revealed metastatic adenocarcinoma, most likely from a lung primary. Ultrasound-guided biopsy is usually indicated and is feasible in most pathological fractures of the appendicular skeleton if there is no known primary.*



SECTION 4

Arthropathies

Osteoarthritis **II**-4-2
Inflammatory Arthritis **II**-4-10
Gout and Pseudogout **II**-4-20
Developmental Hip Dysplasia **II**-4-28



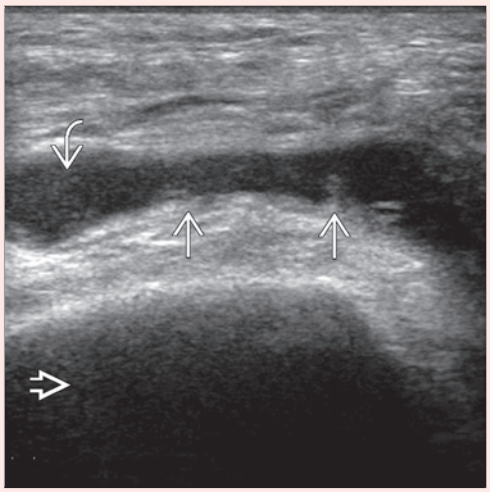
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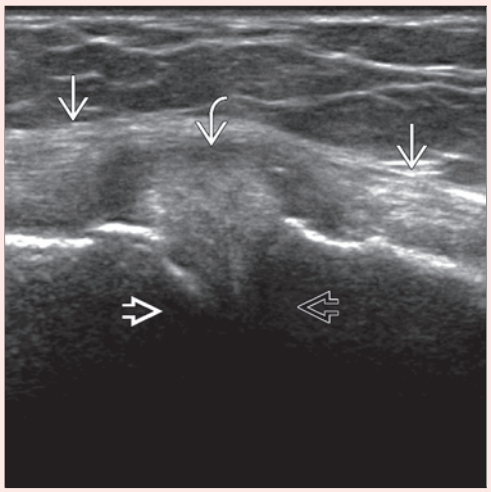
Key Facts

Terminology
- Osteoarthrosis, osteoarthropathy, degenerative joint disease

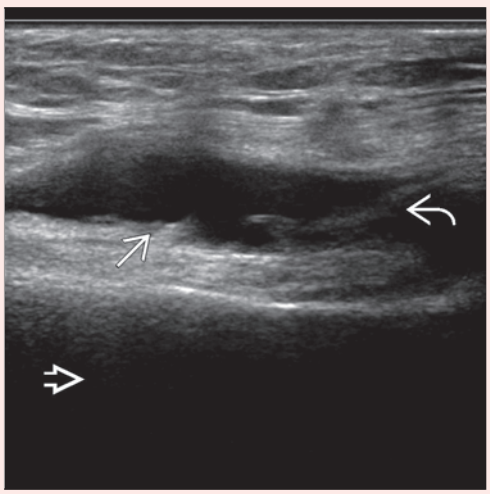
Imaging
- Joint space narrowing, marginal osteophytosis, capsular swelling, synovitis, & effusion are ultrasound signs of OA
- Most commonly affects knee, hip, fingers, 1st carpometacarpal, triscaphe, wrist, & acromioclavicular & tarsal joints
- Ultrasound is increasingly used to determine inflammatory component of OA & differentiate OA from crystal deposition disease or inflammatory arthropathy
- Inflammatory element of OA is characterized by
  - Capsular swelling
  - Joint effusion
  - Synovial proliferation
  - Synovial & pericapsular hyperemia
  - Edema of periarticular soft tissues

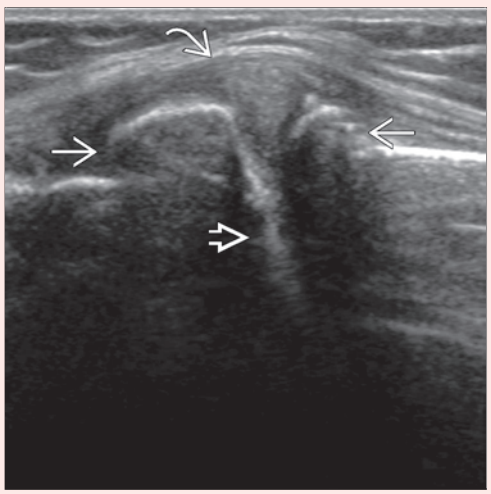
Diagnostic Checklist
- Ultrasound is best for assessing degree of synovitis & guiding intraarticular needle placement
  - Size of effusion, degree of synovial proliferation, & level of hyperemia to gauge inflammatory component of OA
  - Presence of echogenic "comet tail" artifacts as indicator of crystal arthropathy
  - Joint aspiration to check for crystals or infection
- Degree of inflammatory component helps differentiate inflammatory-type OA from inflammatory arthropathy
  - Less pronounced in OA & commensurate with severity of underlying OA





(Left) *Transverse ultrasound shows fluid distension in the medial recess of knee with mild synovial proliferation & slight increase in joint fluid echogenicity. Mild synovial proliferation is common with acute exacerbation of osteoarthritis. Note the medial femoral condyle.* ***(Right)*** *Longitudinal ultrasound shows severe peripheral extrusion of the medial meniscal body displacing the medial collateral ligament. There is moderate to severe joint space narrowing between the medial femoral & tibial condyles.*





(Left) *Longitudinal ultrasound shows anechoic joint effusion & mild synovial proliferation of the suprapatellar recess. Synovial proliferation will also affect synovial plica. Note the femoral shaft.* ***(Right)*** *Longitudinal ultrasound in a patient with knee OA shows moderate marginal osteophytosis, peripheral meniscal extrusion, & moderate to severe medial femorotibial compartment joint space narrowing. The body of the medial meniscus is that portion of the meniscus best appreciated on ultrasound.*

OSTEOARTHRITIS

TERMINOLOGY

Abbreviations
- Osteoarthritis (OA)

Definitions
- Degenerative disease associated with loss of articular cartilage & associated bone & soft tissue abnormalities
  - OA is a disease of the whole joint including bone, cartilage, synovium, capsule, & surrounding muscle
- Secondary: Accelerated osteoarthritis due to existing joint disorder or deformity

IMAGING

General Features
- Best diagnostic clue
  - Articular cartilage thinning accompanied by marginal osteophytosis, subchondral sclerosis, & cyst formation ± inflammatory component
- Location
  - Most commonly affects knee, hip, fingers, 1st carpometacarpal, scapho-trapezium-trapezoid articulation, wrist, acromioclavicular & tarsal joints
  - May affect only localized area or whole of joint
- Morphology
  - Progressive loss of articular cartilage with marginal new bone formation & capsular swelling

Radiographic Findings
- Radiography
  - Primary screening modality for OA
  - Joint space narrowing, subchondral sclerosis, subchondral cysts, & osteophyte formation
    - Mild subluxation, especially in small joints
  - Focal cartilage loss may be present with no joint space narrowing radiographically

MR Findings
- T1WI
  - Cartilage thinning, subchondral cysts, marrow fat signal extending into osteophytes
- T2WI
  - Subchondral edema demonstrated on fat saturation sequences
    - Joint effusion ± intraarticular particulate debris
    - Reactive-type synovitis
  - Periarticular edema with acute exacerbation

Ultrasonographic Findings
- Increasingly used to determine inflammatory component of OA & differentiate OA from crystal or inflammatory arthropathy
- Joint space narrowing, marginal osteophytosis, capsular swelling, synovitis, & effusion
  - Joint space narrowing of some joints (e.g., patellofemoral) may not be readily appreciable
  - Focal cartilage thinning or defects cannot be fully evaluated with ultrasound
- Joint effusion (may be anechoic or slightly echogenic)
  - Medial & lateral patellar recesses of knee usually distend prior to suprapatellar recess
- Mild synovial proliferation is a common finding in osteoarthritis
- Inflammatory element is characterized by
  - Capsular swelling
  - Joint effusion
  - Synovial proliferation (synovial thickening & fronds)
    - Important sign of inflammatory component present in OA
  - Pericapsular & synovial hyperemia on color Doppler
    - Not a very sensitive sign in OA
    - Color Doppler imaging is often negative even with inflammatory component present in OA
      - Indicative of low-grade inflammation seen usually in OA
    - Capsular-synovial hyperemia is difficult to depict in deeper joints such as hip, shoulder, & even knee
    - Contrast-enhanced ultrasound is more sensitive
  - Edema of periarticular tissues (better appreciated with MR than ultrasound)
- Clinical picture, radiographic findings and degree of inflammatory component helps differentiate inflammatory-type OA from inflammatory arthropathy
  - Inflammatory arthropathy has relatively more synovial proliferation & inflammation
  - Also has erosions and other clinical/radiographic features of inflammatory arthropathy
- Particulate debris may be visible within joint fluid
  - Ultrasound can detect radiographically occult intraarticular debris but often cannot determine whether this particulate debris is free or attached
  - Central aspects of joint cannot be fully visualized with ultrasound (better seen with MR)
- Joint subluxation can be exaggerated on ultrasound as dependent on transducer angulation & alignment
- Medial meniscal extrusion is common feature in moderate to severe medial femorotibial OA
- Associated Baker cysts, parameniscal cysts, or ganglia identified by ultrasound with high level of accuracy
  - Inflammatory component, crystal aggregates, & synovial debris can extend into Baker cysts & ganglia
- Ultrasound-guided joint aspiration is helpful to exclude infective, inflammatory arthropathy or crystal deposition disease
  - < 1,000 WBC/μL of synovial fluid is indicative of OA (normally ~ 200 WBC/μL)
  - > 5,000 WBC/μL of synovial fluid is indicative of acute inflammatory or infective arthropathy
  - Specimen for crystal identification should be sent fresh as alcohol will dissolve crystals

Imaging Recommendations
- Best imaging tool
  - Ultrasound for assessing degree of synovitis & guiding intraarticular needle placement
  - MR for assessing cartilage thinning & subchondral bone marrow edema
- Protocol advice
  - Examine joints in systematic fashion
  - Use varying degree of flexion or internal/external rotation to maximize cartilage visibility
  - Use minimal transducer pressure to avoid effacing effusions & blanching color Doppler signal
  - Assess joint space narrowing & marginal osteophytosis as well as medial meniscal extrusion (knee)
  - Assess degree of synovial effusion & echogenicity, degree of synovial proliferation, & hyperemia

- Assess degree of capsular swelling, periarticular edema, bursa, & cysts
- Can semiquantitatively grade synovial hyperemia on color Doppler Imaging
  - Grade 0: No flow
  - Grade 1: Up to 3 color signals
  - Grade 2: > 3 color signals but < 50% of synovial area shows color signal
  - Grade 3: > 50% of synovial area shows color signal
- Can measure degree of medial meniscal extrusion in supine & standing positions
  - Degree of extrusion beyond line joining outer margins of femoral & tibial condyles (inclusive of osteophytes)
    - Normal controls: 3.3 ± 1.0 mm supine, 4.0 ± 1.2 mm standing
    - Osteoarthrosis: 3.6 ± 1.2 mm supine, 5.0 ± 1.7 mm standing

DIFFERENTIAL DIAGNOSIS

Inflammatory Arthritis
- Signs of symmetrical disease
- Positive serological markers
- Increased synovitis relative to degree of OA ± presence of erosions

Crystal Deposition Disease
- Echogenic foci within synovial fluid, synovium, articular cartilage, or menisci
- Otherwise similar to acute OA exacerbation
  - ± discrete hard or soft tophi
  - Ultrasound-guided aspiration for crystals

Focal Chondral Injury
- Best assessed with MR imaging

PATHOLOGY

General Features
- Etiology
  - Common risk factors are age, gender, prior joint injury, obesity, genetic predisposition, & mechanical factors such as malalignment
  - Primary & secondary OA may be different diseases with a common final pathway
    - Secondary OA can often be explained by overload paradigm ("wear & tear")
  - Primary OA does not always reconcile with overload paradigm, e.g., common in sedentary individuals
    - Diminished synovial clearance of normal joint enzymes may be contributory
    - Closed, positive feedback loop may modulate joint enzymatic level & activity
    - Meniscal degeneration & extrusion likely to have etiological role in knee OA

Staging, Grading, & Classification
- Articular cartilage damage (stages)
  - I: Edema (chondromalacia)
  - II: Surface fibrillation with superficial defects
  - III: Deep fibrillation with large deep defects
  - IV: Full thickness defect & subchondral sclerosis, cyst formation ± bony attenuation

Gross Pathologic & Surgical Features
- Degraded cartilage with fissuring ± ulcerated cartilage surface & loss of surface sheen

Microscopic Features
- Diminution of chondrocytes in superficial zones with chondrocyte swelling
- Cartilage matrix loses its ability to stain for proteoglycans
- Neovascularity penetrates layer of calcified cartilage, & new chondrocytes extend up from deeper layers
- Hypertrophied synovium with variable plasma cell & lymphocytic infiltrate

CLINICAL ISSUES

Presentation
- Most common signs/symptoms
  - Pain aggravated by movement & joint swelling
- Clinical profile
  - Catching, locking, or grinding in older patient

Demographics
- Age
  - Typically older patients (> 50 years)
- Gender
  - Female predominance, accelerated joint degeneration occurs after menopause

Natural History & Prognosis
- Progressive debilitating disease

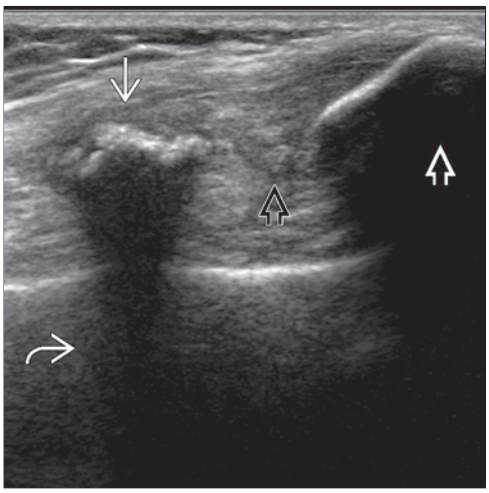
Treatment
- Conservative
  - Minimize overloading, e.g., weight loss
  - Muscle strengthening
  - Pain management by analgesics or NSAIDs
  - Viscosupplementation via intraarticular injection
  - Glucosamine & chondroitin by oral supplements
- Surgical
  - Arthroscopy (debridement)
  - Resurfacing procedure (hip or knee)
  - Tibial osteotomy to redistribute weightbearing load
  - Prosthetic joint replacement

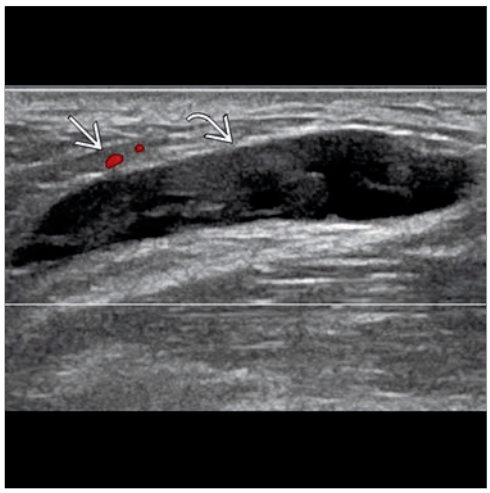
DIAGNOSTIC CHECKLIST

Consider
- Size of effusion, degree of synovial proliferation, & level of hyperemia to gauge inflammatory component of OA
- Presence of echogenic "comet tail" artifacts as indicator of crystal arthropathy
- Joint aspiration to check for crystals or infection

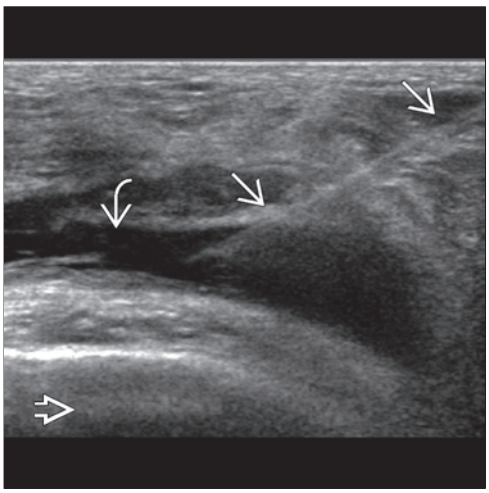
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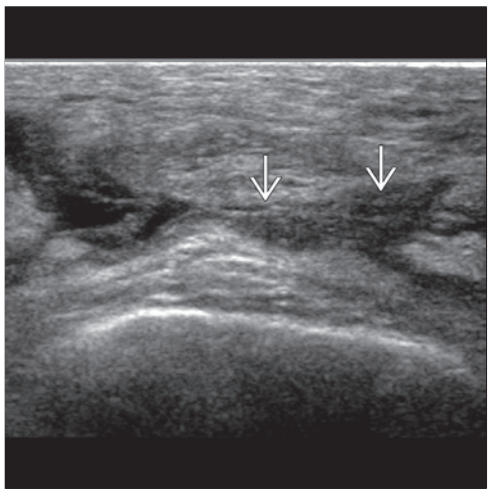
1. Beitinger N et al: The value of colour Doppler sonography of the knee joint: a useful tool to discriminate inflammatory from non-inflammatory disease? Rheumatology (Oxford). 52(8):1425-8, 2013



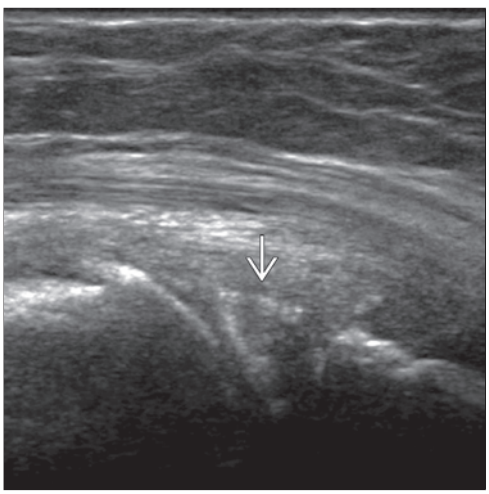


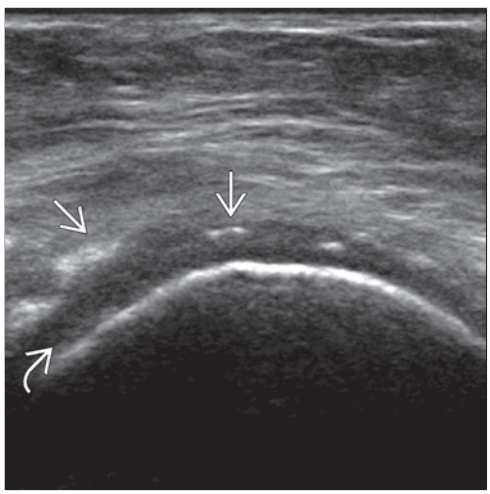
(Left) *Longitudinal ultrasound shows a calcified intraarticular body in the suprapatellar pouch* ➔. *There is no suprapatellar pouch effusion & hence the joint cavity* ⇨ *is effaced. Patellar bone* ➔ *& femoral shaft* ➔ *are shown.* ***(Right)*** *Longitudinal color Doppler ultrasound shows synovial proliferation* ➔ *within a distended Baker cyst in a patient with knee OA. Knee inflammation may also manifest in accompanying Baker cyst. No visible color flow* ➔ *within the cyst reflects relatively low-grade inflammation.*





(Left) *Transverse ultrasound shows needle* ➔ *placement in lateral recess of knee* ➔ *for joint aspiration. Ultrasound ensures proper needle placement for joint aspiration or intraarticular therapeutic injection. Note the lateral femoral condyle* ➔. ***(Right)*** *Transverse ultrasound in the same patient following fluid aspiration shows mild residual synovial proliferation* ➔. *Ultrasound is very helpful in determining the relative component of knee swelling due to effusion or synovial proliferation.*

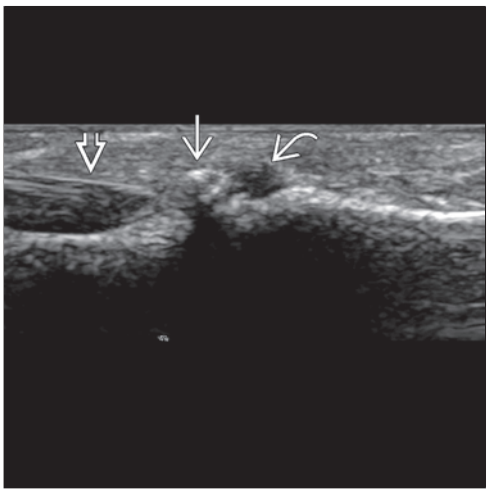


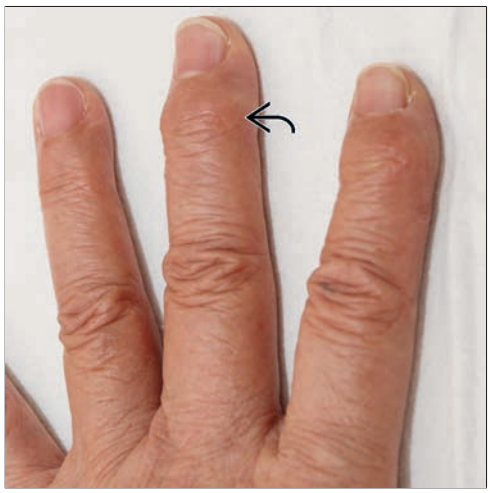


(Left) *Longitudinal ultrasound in a patient with knee OA shows rim-like calcification* ➔ *of the medial meniscus from chondrocalcinosis. Chondrocalcinosis can be seen more easily in the medial meniscus than in the lateral meniscus. Distal femoral & proximal tibia are shown.* ***(Right)*** *Longitudinal ultrasound shows echogenic calcification both on the surface* ➔ *& embedded into the articular cartilage* ➔ *on the medial femoral condyle posteriorly. This distribution favors calcium pyrophosphate deposition over gout.*

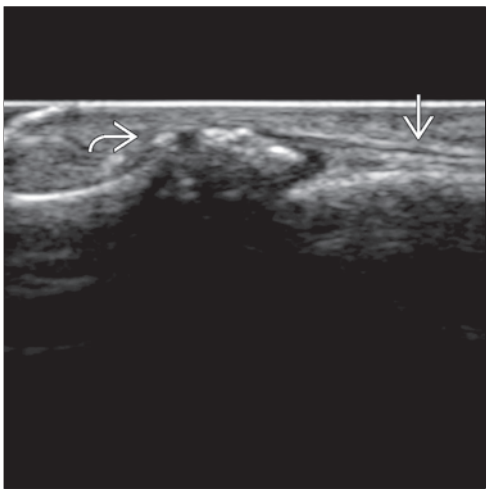
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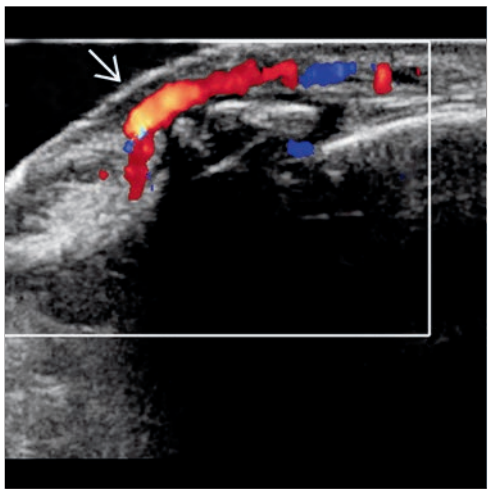
(Left) *Longitudinal ultrasound of the finger shows prominent marginal osteophytosis ➔ of the distal interphalangeal joint with mild capsular swelling ➔. Finger flexion may help to better show the distal interphalangeal joint space. The nail ➔ overlies the distal phalanx.* ***(Right)*** *Clinical photograph of a patient with middle finger distal interphalangeal joint pain shows associated swelling ➔ & mild flexion deformity of the distal interphalangeal joint.*



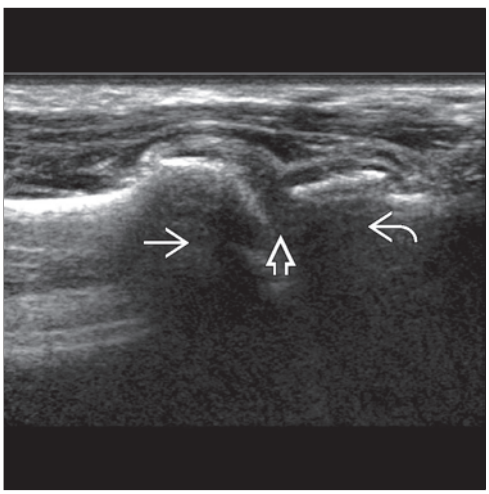


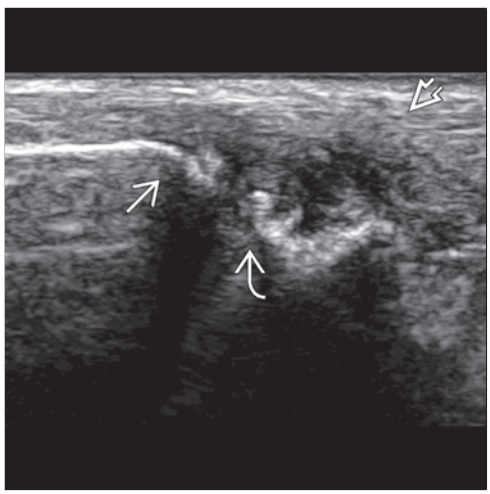
(Left) *Longitudinal ultrasound of the middle finger in the same patient as previous image shows prominent marginal hyperostosis ➔ around the distal interphalangeal joint. The joint line is obscured. Note insertion of extensor tendon ➔ into the hyperostotic bone.* ***(Right)*** *Longitudinal color Doppler ultrasound of the same joint in a slightly flexed position shows marked paraarticular hyperemia ➔, consistent with an acute exacerbation of inflammatory osteoarthritis.*

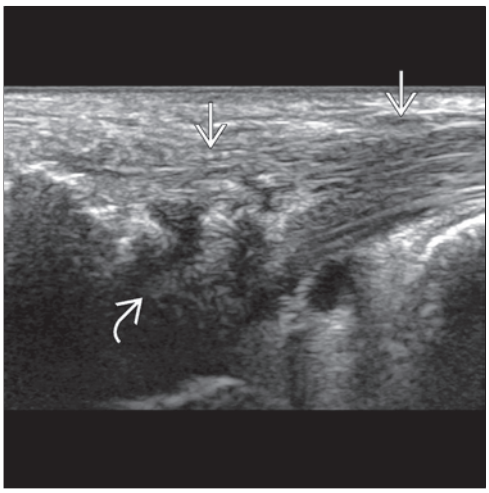


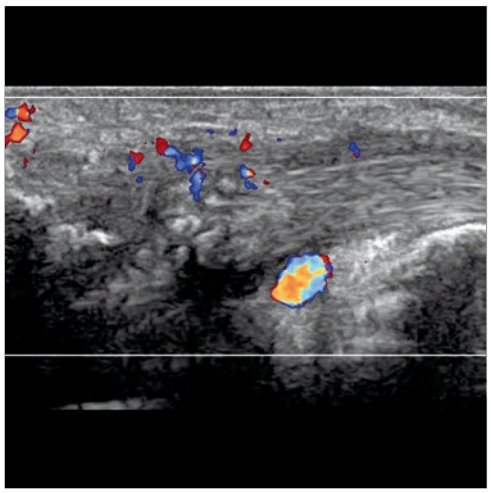


(Left) *Longitudinal ultrasound shows only mild joint space narrowing of the 1st metacarpophalangeal joint ➔ between the metacarpal base ➔ & the trapezium ➔, consistent with mild osteoarthritis. No periarticular edema is present.* ***(Right)*** *Longitudinal ultrasound shows severe OA of the 1st metacarpophalangeal joint with marginal osteophytosis of the trapezium ➔, subluxation of the 1st metacarpal base ➔, & moderate periarticular soft tissue edema ➔.*

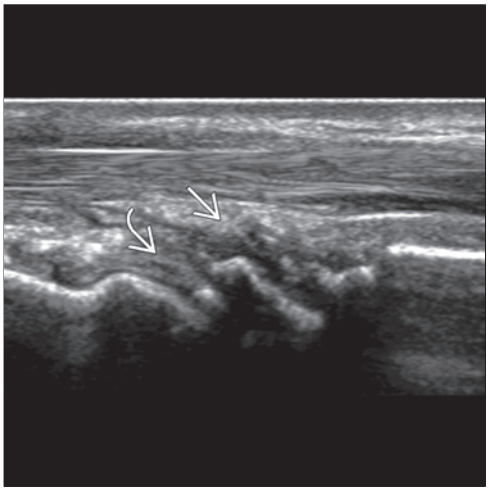


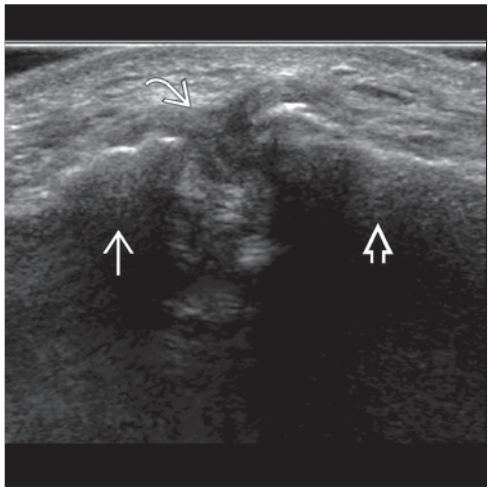




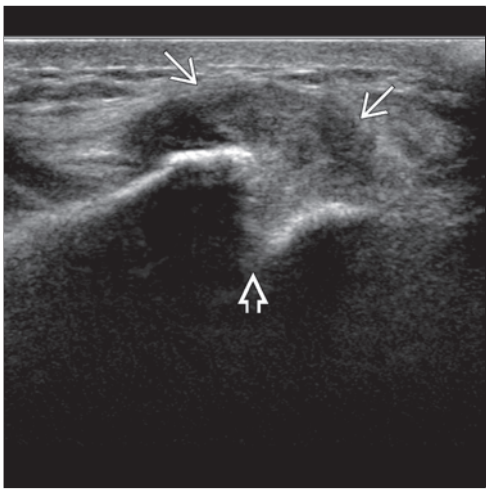


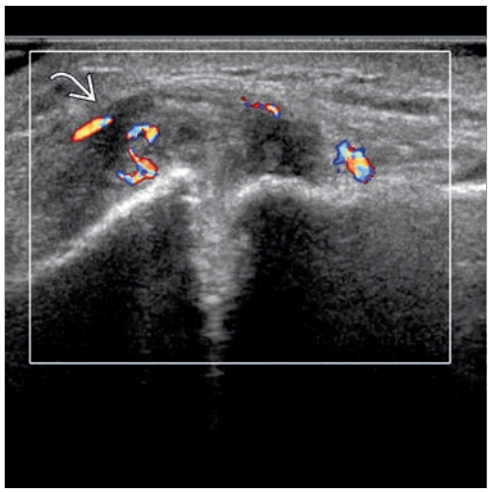
(Left) *Longitudinal ultrasound shows severe flexor carpi radialis (FCR) insertional tendinosis* ➔ *& triscaphe OA* ➔. *Individual components of the triscaphe articulation (distal pole scaphoid, trapezium, & trapezoid) cannot be delineated.* ***(Right)*** *Longitudinal color Doppler ultrasound of the same area as previous image shows moderate hyperemia of the FCR insertional area. Anatomical proximity is felt to account for the relationship between triscaphe osteoarthritis, 1st CMC OA, & FCR tendinosis.*





(Left) *Longitudinal ultrasound of wrist OA shows severe joint space narrowing at the dorsal aspect of the radiolunate* ➔ *& lunocapitate* ➔ *articulations with minimal synovial proliferation.* ***(Right)*** *Transverse ultrasound shows moderate OA of the acromioclavicular joint with moderate joint space widening* ➔ *(rather than narrowing) between the irregular joint surfaces of the clavicle* ➔ *& acromion* ➔. *Osteoarthritis is not invariably associated with capsular thickening or joint space narrowing.*

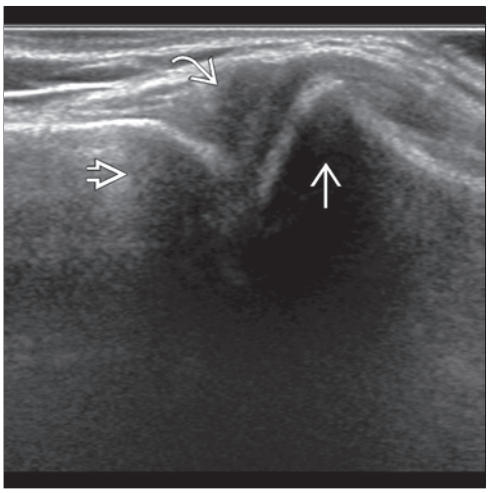




(Left) *Transverse ultrasound shows severe capsular swelling* ➔ *of the acromioclavicular joint with moderate joint space narrowing* ➔. ***(Right)*** *Transverse color Doppler ultrasound shows moderate capsular hyperemia* ➔ *consistent with acute inflammatory-type osteoarthropathy. Effusion within the AC joint is rarely seen, making it more difficult to separate the capsule from the synovium & appreciate the actual joint space.*

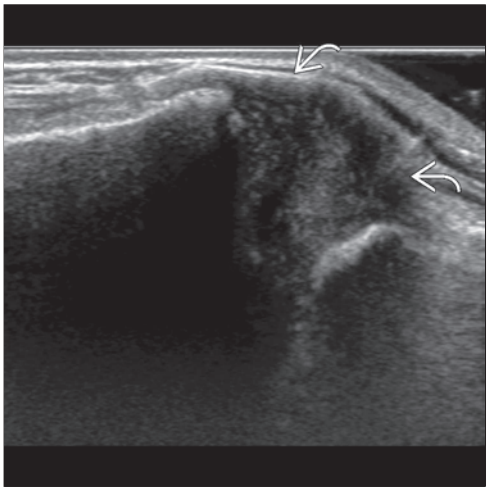
OSTEOARTHRITIS

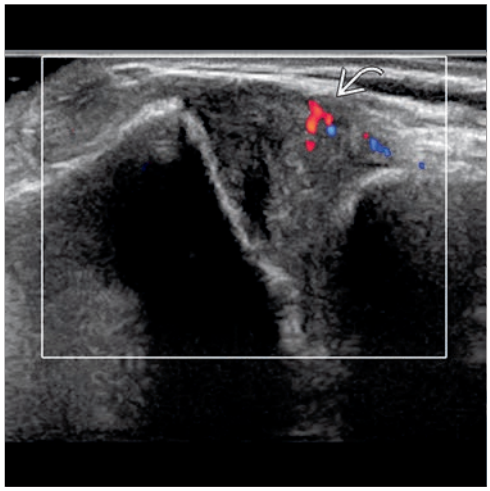
(Left) *Transverse ultrasound shows mild capsular swelling of the sternoclavicular joint secondary to mild osteoarthritis. The medial end of the clavicle normally protrudes beyond the manubrium.* ***(Right)*** *Clinical photograph shows moderate swelling of the right sternoclavicular joint. The superficial location of this joint means that any swelling or disfiguration will become readily apparent clinically. This joint is very accessible to ultrasound as a first line investigation.*





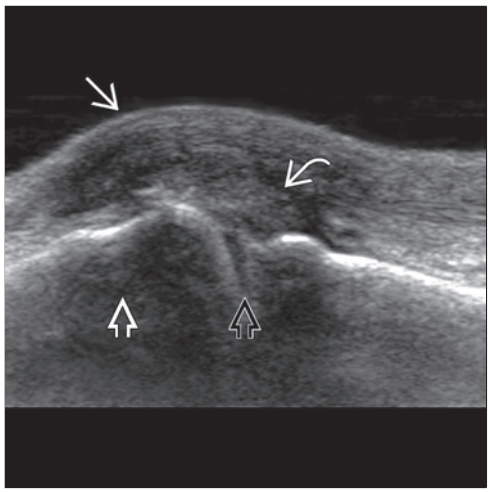
(Left) *Transverse ultrasound in the same patient shows moderate capsular swelling of the right sternoclavicular joint.* ***(Right)*** *Transverse color Doppler ultrasound of the same joint shows mild capsular hyperemia. In this situation, distinction between an inflammatory-type OA & and inflammatory arthropathy is difficult. This distinction is best made on clinical & serological grounds as further imaging with CT or MR is often not helpful in this context.*



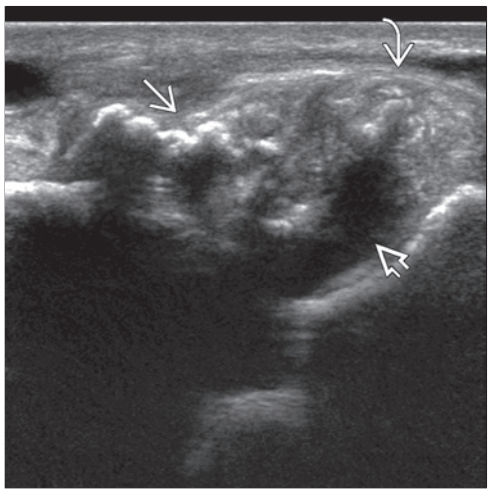


(Left) *Clinical photograph shows a patient with pain & swelling on the medial aspect dorsum of the midfoot.* ***(Right)*** *Longitudinal ultrasound of the same patient shows moderate OA of the 1st tarsometatarsal joint with joint space narrowing, capsular thickening, & periarticular soft tissue edema. This pattern is consistent with inflammatory-type OA. There is no evidence of gout. Color Doppler ultrasound (not shown) showed mild capsular hyperemia. Note the medial cuneiform.*

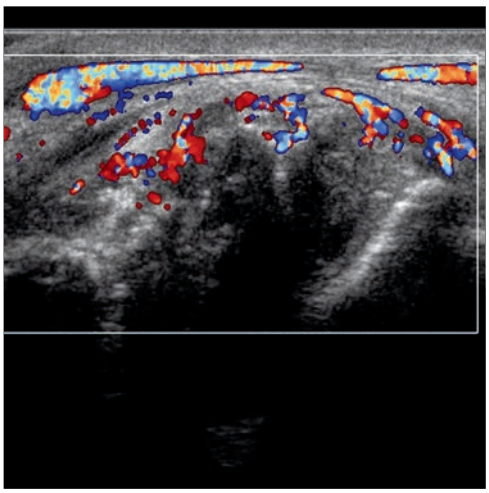


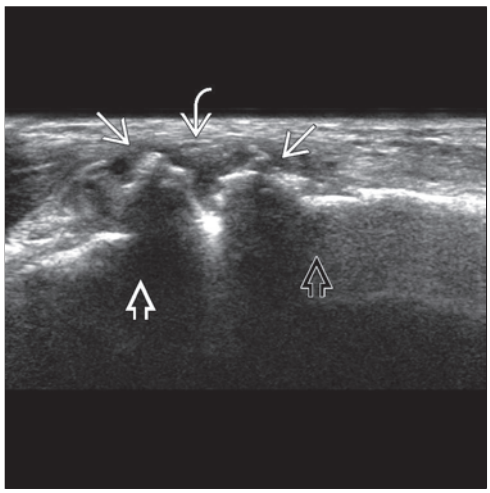




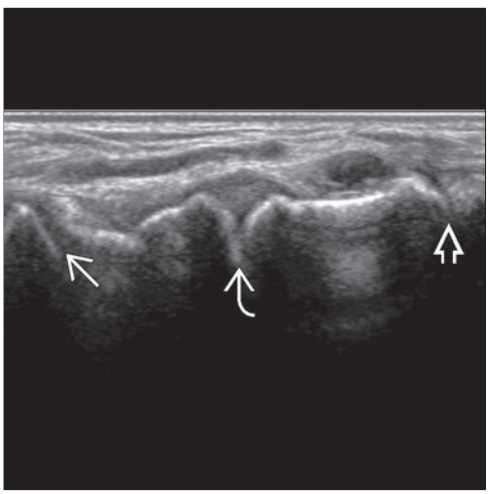


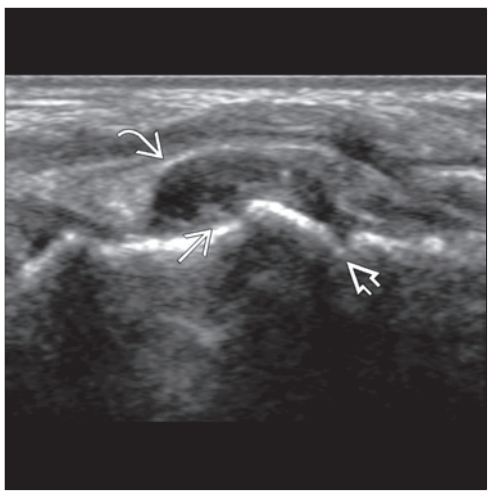
(Left) *Clinical photograph of a diabetic patient with progressive ankle swelling shows severe deformity.* ***(Right)*** *Longitudinal ultrasound in the same patient shows severe ankle arthropathy with chronic synovial thickening, osseous fragmentation, debris, & a small effusion. Possibilities include either a diabetic neuroarthropathy or, less likely, a TB arthropathy. Ultrasound-guided synovial biopsy revealed acute on chronic inflammation but no evidence of infection.*





(Left) *Longitudinal color Doppler ultrasound in the same patient shows quite marked periarticular hyperemia. Overall appearances are consistent with subacute exacerbation of diabetic neuroarthropathy.* ***(Right)*** *Longitudinal ultrasound shows severe OA between the intermediate cuneiform & 2nd metatarsal bone associated with capsular swelling & marginal osteophytosis. Mild marginal hyperemia on color Doppler imaging was present (not shown).*





(Left) *Longitudinal ultrasound shows moderate OA of midfoot with joint space narrowing, capsular swelling, & marginal osteophytosis at the talonavicular, navicular-cuneiform, & 2nd tarsometatarsal articulations.* ***(Right)*** *Longitudinal ultrasound of the same patient shows a medium-sized effusion of the 2nd tarsometatarsal joint with dorsal capsular distension. Synovial proliferation is present, which helps to distinguish this from a periarticular ganglion.*

INFLAMMATORY ARTHRITIS

Key Facts

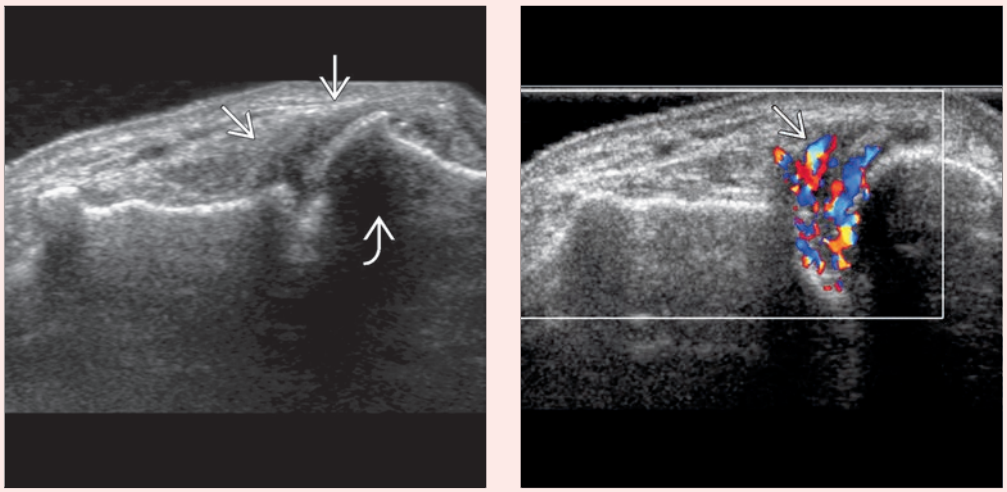
Terminology

- Systemic autoimmune inflammatory disorders primarily affecting synovial membrane with secondary involvement of articular surface and bone

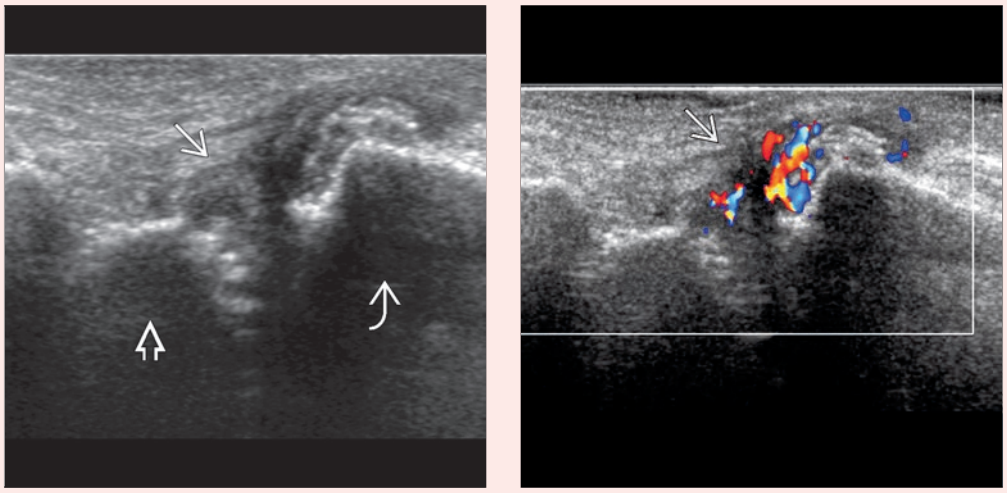
Imaging

- Thickened hyperemic synovium
- Wrist joint > small joints of hand and feet
- Any synovial-lined joint
- Mono- to oligo- to polyarthropathy
- **Effusion**
  - Sensitive though nonspecific indicator of synovitis
- **Thickened hypoechoic synovium (pannus) is most common finding**
  - Hypoechoic > hyperechoic
  - Ultrasound is 10x more sensitive than clinical examination in detecting early MTP joint synovitis
- **Marginal bony erosions**
  - Focal juxtacortical cortical disruption with adjacent synovitis
  - 6.5x more metacarpophalangeal erosions detected with ultrasound than radiography
  - 28% false-positive rate for ultrasound detection of erosions compared with micro-CT
- **Cartilage loss**
  - Ultrasound is good but better assessed with radiography or MR
- **Periarticular soft tissue changes**
  - Tendon disease, nerve entrapment, bursal distension, rheumatoid nodules and features of enthesopathy are all well seen with ultrasound
- **Color Doppler (CD) is helpful in distinguishing synovial proliferation from joint fluid**
  - Allows level of disease activity to be assessed
  - Active pannus shows high flow on CD
  - Inactive synovial proliferation → low/absent flow

(Left) *Transverse ultrasound shows moderate synovial proliferation of the dorsal aspect of the distal radioulnar joint in a patient with rheumatoid arthritis. There is moderate dorsal subluxation of the ulnar head. **(Right)** Transverse color Doppler ultrasound of the same patient shows severe synovial hyperemia, indicative of active synovitis. Determining the degree of synovial vascularity is the best way to gauge synovial activity.*



(Left) *Longitudinal ultrasound of the same patient shows moderate-severity synovial proliferation of the ulnodorsal wrist, with thickened synovium filling the space between the ulnar head and the moderately eroded lunate. **(Right)** Longitudinal color Doppler ultrasound in the same patient shows moderate hyperemia of this thickened synovium, indicative of active synovitis.*



INFLAMMATORY ARTHRITIS

TERMINOLOGY

Synonyms
- Rheumatoid arthritis (RA), juvenile inflammatory arthropathy (JIA), systemic lupus erythematosus (SLE), psoriatic arthropathy ankylosing spondylitis (AS)

Definitions
- Systemic autoimmune inflammatory disorders, primarily affecting either synovial membrane or enthesis with secondary involvement of articular surface and bone

IMAGING

General Features
- Best diagnostic clue
  - Thickened hyperemic synovium
- Location
  - Wrist joint
  - Intercarpal joints, carpometacarpal, metacarpophalangeal (MCP), metatarsophalangeal (MTP), and interphalangeal joints
  - Elbow, shoulder, hip, knee, ankle, intertarsal joints
  - Any synovial-lined joint
- Size
  - Single (monoarthopathy), to few (oligoarthropathy), to many (polyarthropathy) joints involved
- Morphology
  - Synovial thickening, effusion, erosions, joint space narrowing, deformity, subluxation, bony resorption, ankylosis

Radiographic Findings
- Radiography
  - Often normal in early stages of disease
  - Soft tissue swelling, juxtaarticular osteopenia (demineralization), joint space narrowing (cartilage loss), marginal bony erosions
    - Pattern of disease is more important than individual radiographic signs
  - Joint obliteration and ankylosis, particularly of carpus
  - Arthritis mutilans and joint deformities ("swan neck", "boutonnière") are less commonly seen now with disease-modifying therapy

MR Findings
- T1WI
  - More sensitive at depicting early erosions against background of hyperintense marrow fat
  - Hypertrophied hypointense synovium
- T2WI FS
  - Shows fluid and edematous tissue (synovium, erosions, subchondral marrow, paraarticular soft tissues)
  - Effusions and pannus are both hyperintense and may not be readily distinguishable
  - Joint space narrowing, erosions, bone marrow edema graded semi-quantitatively (Outcome Measures in Rheumatology Clinical Trials [OMERACT] score)
- T1WI C+
  - Effusion fluid will not enhance while pannus and acute or subacute erosions will enhance vigorously
  - Contrast enhancement is necessary to appreciate activity of synovitis
    - Segmentation subtraction technique allows quantification of enhancing synovial volume
    - Dynamic perfusion imaging provides quantifiable perfusion parameters

Ultrasonographic Findings
- Grayscale ultrasound
  - **Effusion**
    - Sensitive though nonspecific indicator of synovitis
  - **Thickened hypoechoic synovium (pannus) is most common finding**
    - Usually hypoechoic (though may be iso- or hyperechoic to subdermal fat)
    - Synovial thickening → diffuse, frond-like, lobulated or nodular proliferation
    - May resemble hypoechoic or echogenic synovial fluid
    - Joint fluid is normally anechoic
    - Precipitated fibrin is seen as small floating hyperechoic aggregates
    - Ultrasound is 10x more sensitive than clinical examination in detecting early MTP joint synovitis
  - **Marginal bony erosions**
    - Focal cortical defect with adjacent synovitis
    - 6.5x more MCP erosions are detected with ultrasound than radiography
    - 28% false-positive rate for ultrasound detection of erosions compared with micro-CT
  - **Cartilage loss**
    - Ultrasound is good, but better assessed with radiography or MR
  - **Periarticular soft tissue changes**
    - Tendon disease, nerve entrapment, bursal distension, rheumatoid nodules, and features of enthesopathy are all seen well with ultrasound
  - US-guided joint aspiration/biopsy or injection is useful useful for both diagnosis and Rx
    - Leucocyte infiltration of synovium or joint fluid is earliest indicator of joint inflammation
- Color Doppler
  - **Color Doppler (CD) is helpful in distinguishing synovial proliferation from joint fluid**
  - Allows level of disease activity to be assessed
    - Active pannus shows high flow on CD
    - Inactive synovial proliferation → low/absent flow
    - Grade level of synovial vascularity semiquantitatively (as absent, mild, moderate, or severe) or quantitatively with computer-assisted measurement
    - Quantitative or semiquantitative assessment of synovial vascularity with microbubble contrast-enhanced Doppler ultrasound
    - Spectral analysis: Active disease associated with decreased resistive index (RI)

Imaging Recommendations
- Best imaging tool
  - Ultrasound
    - As most joints are accessible and multiple joints can be examined during the same examination
- Protocol advice
  - High-resolution (≥ 10 MHz) transducer with schematic examination of each symptomatic joint

- Examine all accessible surfaces of joint
- As well as color Doppler, probe compression can help differentiate fluid from synovium
  - Fluid displaced rather than compressed by probe compression
- Always demonstrate erosions in 2 planes
  - Beware of normal osseous contour; compare with opposite side

DIFFERENTIAL DIAGNOSIS

Osteoarthritis

- Joint space narrowing with marginal osteophytosis and absence of erosions
  - Synovial proliferation and hyperemia not as pronounced as in inflammatory arthritis
- Inflammatory erosive osteoarthritis is characterized by small joint involvement, erosions and synovial proliferation similar to other inflammatory arthritides
  - Clinical course, radiography, and laboratory tests are helpful to distinguish

Septic Arthritis

- Often indistinguishable from inflammatory monoarthropathy
- Joint aspiration is indicated

Crystal Deposition Disease

- Very similar to acute inflammatory monoarthropathy
- ± echogenic foci within joint fluid, synovium, or articular cartilage due to crystal deposition
- Joint aspiration helpful

PATHOLOGY

Gross Pathologic & Surgical Features

- Bilateral, symmetrical joint involvement
- RA is primarily a disease of synovial inflammation
- Synovial inflammatory mass (pannus) leads to marginal erosions at junction of articular cartilage and bare area of bone
- Chronic synovitis/inflammation → capsular, ligamentous laxity and tendon attrition/rupture
- Caput ulnar syndrome
  - Laxity of radioulnar and ulnocarpal ligaments
  - → dorsal subluxation of ulna head → extensor carpi ulnaris tendon attrition and tearing

Microscopic Features

- Synovial inflammation
  - Hyperplasia of synovial cells with lymphocytic and plasma cell infiltrate
  - Synovial membrane exudes fibrinous exudate
- Rheumatoid factor
  - Serum IgM antibody present in 70% of RA patients
  - The higher the titer, the greater the likelihood of RA
    - RF titer ≥ 1:40 = 28% likelihood of RA: RF titer ≥ 1:640, 99% likelihood of RA
  - RF-positive RA patients experience more aggressive erosive joint disease and extraarticular manifestations than RF-negative patients
  - Anti-citrullinated protein antibodies (ACPA)
  - Associated with more severe disease progression

CLINICAL ISSUES

Presentation

- ACR/EULAR Classification Criteria for RA (2010) are accessible on web-based application, RheumaHelp and used as guide to establish clinical diagnosis
  - Considers the following features of RA
    - Joint distribution (0-5)
      - Number of large or small joint affected
  - Serology (0-3)
    - Rheumatoid factor and ACPA positivity
  - Symptom duration (0-1)
    - < 6 weeks or ≥ 6 weeks
  - Acute phase reactants (0-1)
    - C-reactive protein and ESR levels

Demographics

- Age
  - 25-60 years most common
  - Peak incidence: 40-60 years
- Gender
  - M:F = 1:3
- Epidemiology
  - RA incidence = 1% of population

Natural History & Prognosis

- Progressive disease with exacerbations
- Progressive joint destruction
- Complications
  - Progressive joint malalignment with secondary osteoarthritis
  - Tendon attrition and rupture
  - Median and ulnar nerve entrapment
  - Rheumatoid nodules at pressure sites
  - Avascular necrosis
  - Pulmonary (granulomas, fibrosis, pleuritis), ocular (episcleritis), stromal (Sjögren syndrome), and renal
  - Lymphadenopathy, splenomegaly (Felty syndrome)

Treatment

- Conservative
  - Nonsteroidal anti-inflammatory agents
    - Inhibit prostaglandin synthesis by blocking cyclooxygenase enzymes, COX-1 and COX-2
  - Corticosteroids (systemic or intraarticular)
  - Disease-modifying agents
    - Methotrexate, infliximab, antimalarials, gold salts, sulfasalazine, cyclophosphamide, azathioprine
- Surgical
  - Synovectomy and tenosynovectomy
  - Tendon repair
  - Arthroplasty or arthrodesis

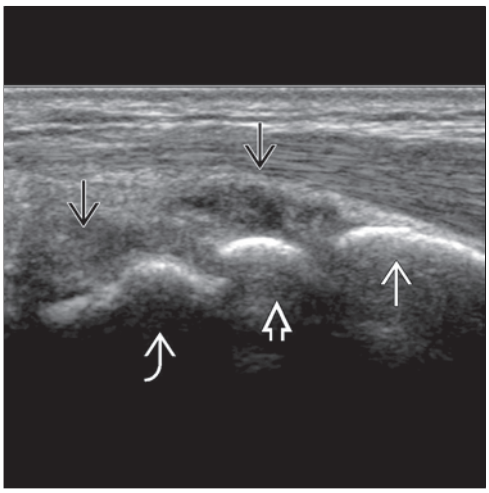
DIAGNOSTIC CHECKLIST

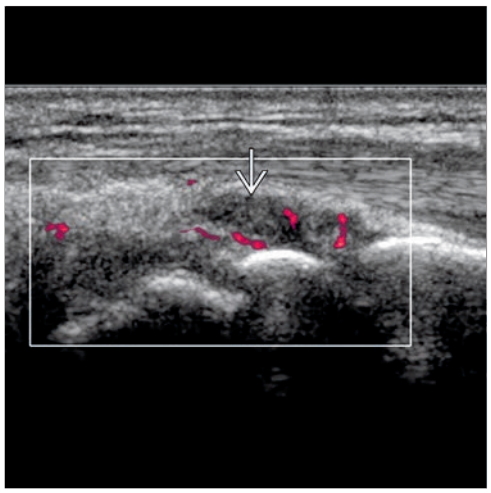
Image Interpretation Pearls

- Use compression and color Doppler to distinguish hypoechoic proliferative synovium from fluid
- Aspirate any joint fluid if septic arthritis or crystal deposition disease suspected

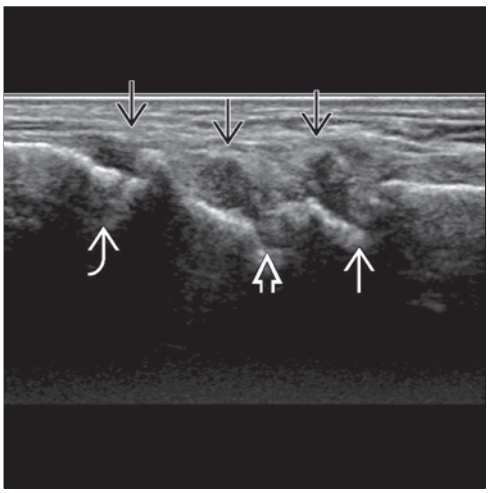
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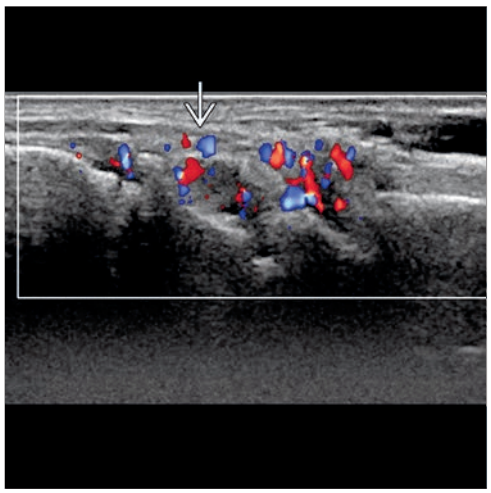
1. Grainger AJ et al: Rheumatoid arthritis. Semin Musculoskelet Radiol. 17(1):69-73, 2013



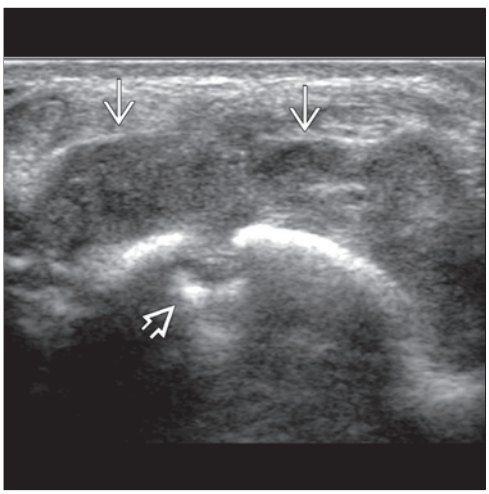


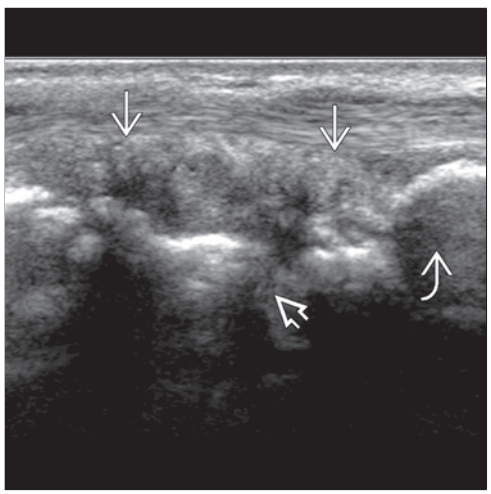
(Left) *Longitudinal ultrasound of the dorsal aspect of the wrist shows moderate synovial proliferation between the distal radius and the lunate as well as between the lunate and the capitate. As a general rule, active synovium tends to be more hypoechoic on account of its increased water content.* ***(Right)*** *Longitudinal Doppler ultrasound shows mild synovial hyperemia, most pronounced at the radiolunate articulation. This is indicative of mild synovial activity.*





(Left) *Longitudinal ultrasound shows moderate carpal synovial proliferation in a patient with rheumatoid arthritis with widening secondary to erosion at the radiolunate and lunocapitate articulations, but the joint space narrowing is due to cartilage loss without erosion at the carpometacarpal articulation.* ***(Right)*** *Longitudinal color Doppler ultrasound in the same patient shows moderate-severity synovial hyperemia, indicative of moderate synovitis.*

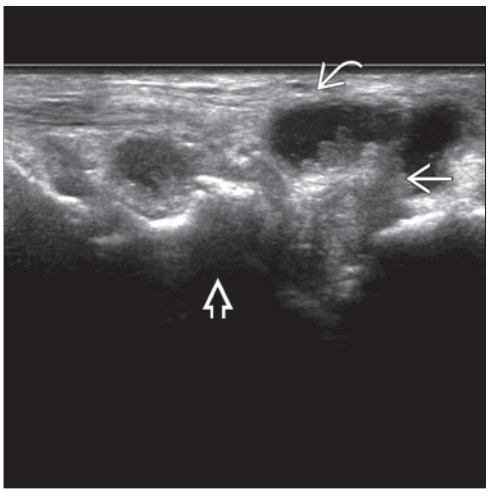


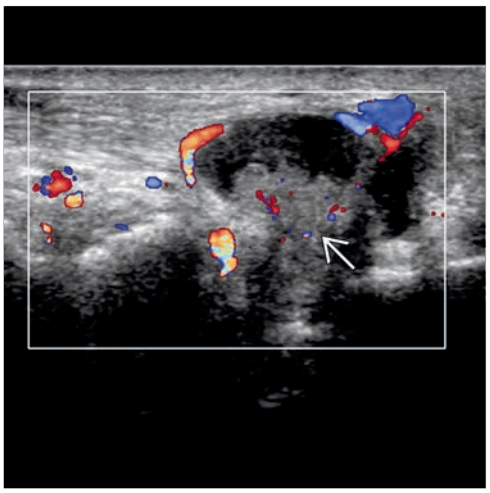


(Left) *Transverse ultrasound in a patient with chronic rheumatoid arthritis and carpal fusion shows severe synovial proliferation on the dorsum of the wrist joint with a moderate-sized discrete bony erosion on the dorsal aspect of the fused scapholunate articulation.* ***(Right)*** *Longitudinal ultrasound of same patient shows moderate-severity synovial proliferation on the dorsal aspect of a largely ankylosed carpus. The midcarpal articulation is still not fused. The ulnar head is mildly subluxed.*

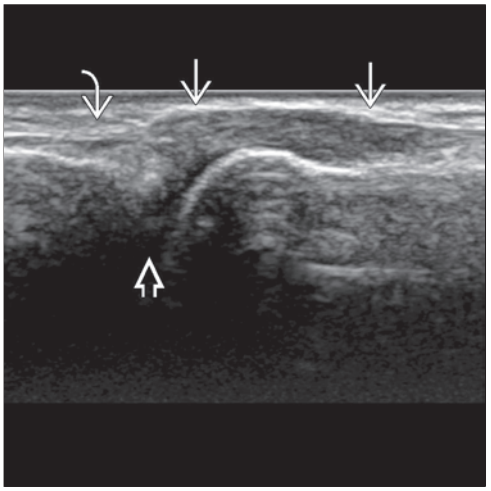
INFLAMMATORY ARTHRITIS

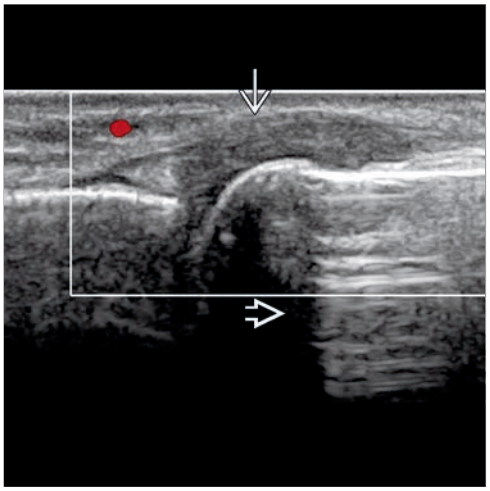
(Left) *Longitudinal ultrasound in a patient with end-stage rheumatoid arthritis shows severe arthropathy of carpus with largely fused carpus. There is outpouching of both thickened synovium and synovial fluid dorsally. The thickened synovium shows villous proliferation.* ***(Right)*** *Longitudinal color Doppler ultrasound of same patient shows moderate periarticular and synovial hyperemia, indicative of moderate-severity disease activity.*



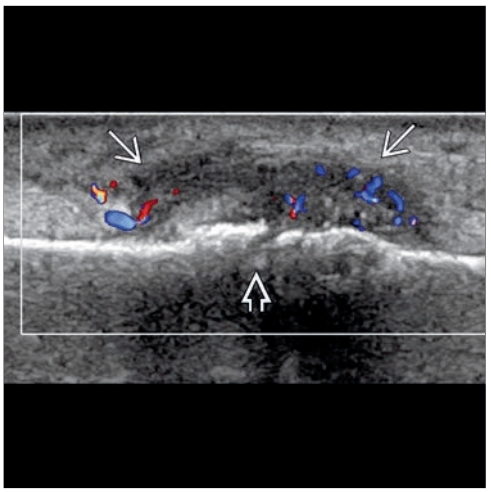


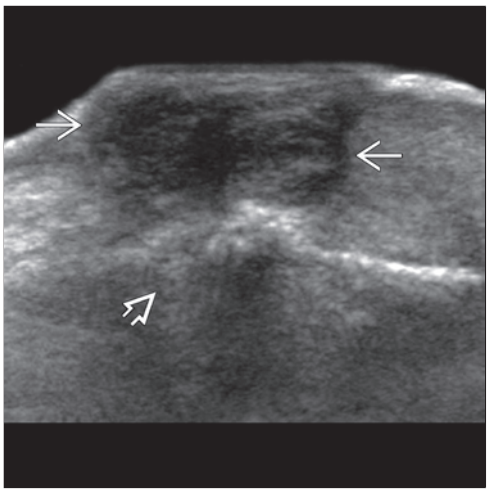
(Left) *Longitudinal ultrasound in a rheumatoid arthritis patient shows moderate synovial proliferation distending the dorsal aspect of the metacarpophalangeal joint. Mild joint space narrowing is present. The thin extensor tendon is dorsally displaced.* ***(Right)*** *Longitudinal color Doppler ultrasound in same patient shows no synovial hyperemia, indicative of inactive disease. Reverberation artefact is present between cortex and transducer with evenly spaced lines due to range ambiguity.*

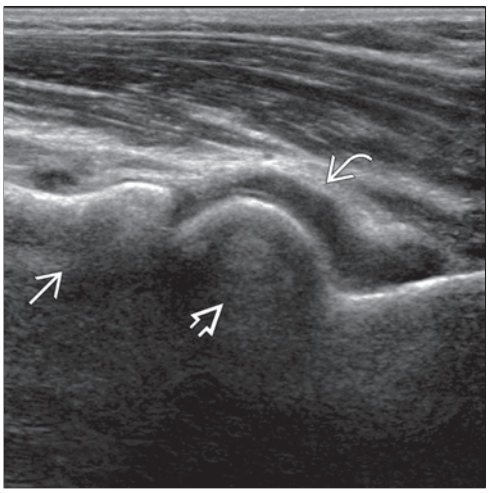


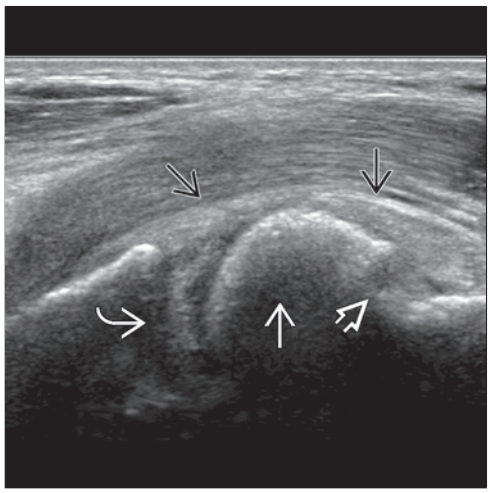


(Left) *Longitudinal color Doppler ultrasound in a rheumatoid arthritis patient shows moderate synovial proliferation and hyperemia on the dorsum of the proximal interphalangeal joint of the index finger. There is severe joint space narrowing.* ***(Right)*** *Longitudinal ultrasound of another finger in the same patient shows a well-defined hypoechoic rheumatoid nodule dorsal to an erosive arthropathy of the middle interphalangeal joint.*

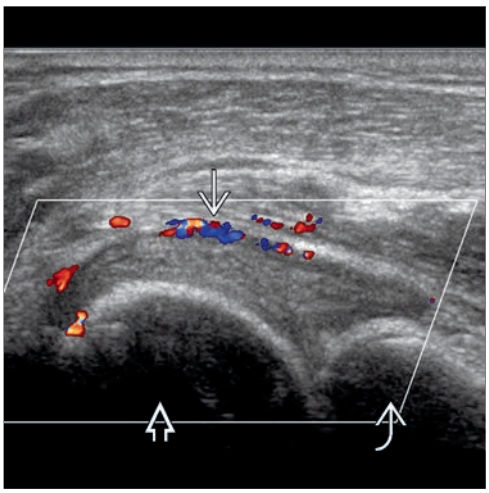


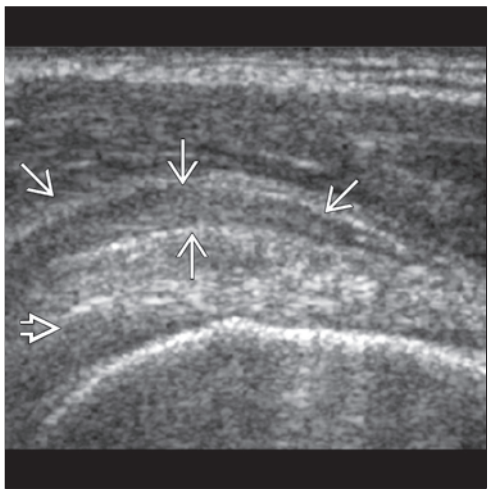




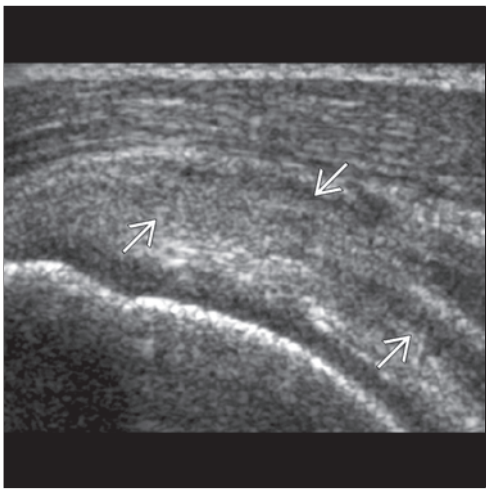


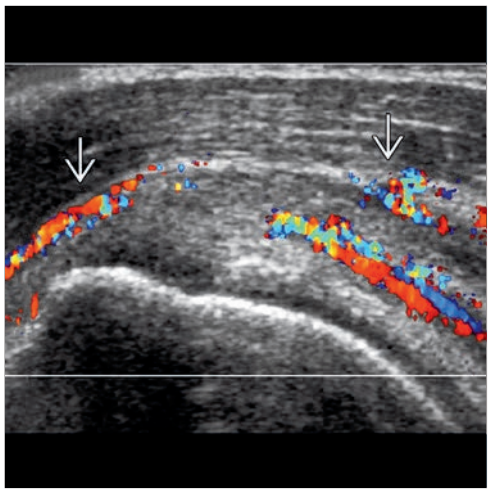
(Left) *Longitudinal ultrasound in a patient with early rheumatoid arthritis shows moderate synovial proliferation and effusion of the elbow joint. There is no erosive change of either the capitellum or the radial head.* ***(Right)*** *Longitudinal ultrasound in a patient with longstanding rheumatoid arthritis shows more severe synovial proliferation on the flexor aspect of the elbow joint with a moderate-sized discrete erosion at the proximal end of the capitellum. There is also moderate subchondral resorption of the radial head.*





(Left) *Transverse color Doppler ultrasound in RA patient shows moderate synovial proliferation of the glenohumeral joint posteriorly with moderate severity synovial hyperemia. Bear in mild that color Doppler signal detection is less sensitive for the deeper joints (e.g., shoulder, hip). No erosions of the humeral head or glenoid are evident.* ***(Right)*** *Longitudinal ultrasound shows a moderate severity echogenic subacromial-subdeltoid bursitis in patient with SLE. The underlying supraspinatus tendon is normal.*



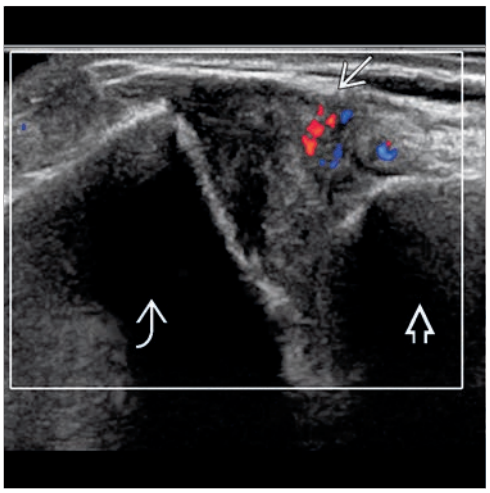


(Left) *Transverse ultrasound in same patient as previous image shows moderate to severe synovial proliferation extending from subacromial-subdeltoid bursa into substance of the supraspinatus tendon. This intratendinous synovial proliferation helps to explain the severe tendon attenuation sometimes seen in chronic inflammatory arthropathy.* ***(Right)*** *Transverse color Doppler ultrasound in the same patient shows severe hyperemia of this synovial proliferation. One must consider an inflammation arthropathy with this degree of subacromial-subdeltoid bursitis.*

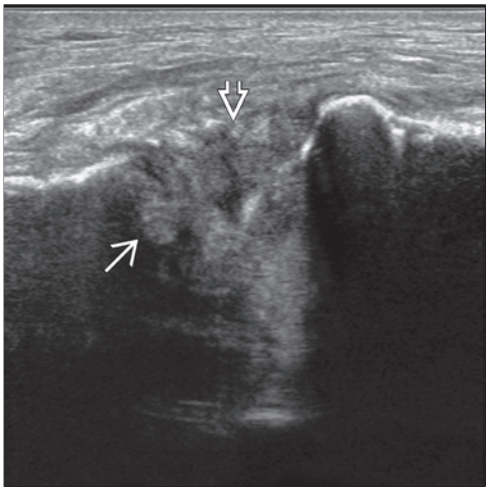
INFLAMMATORY ARTHRITIS

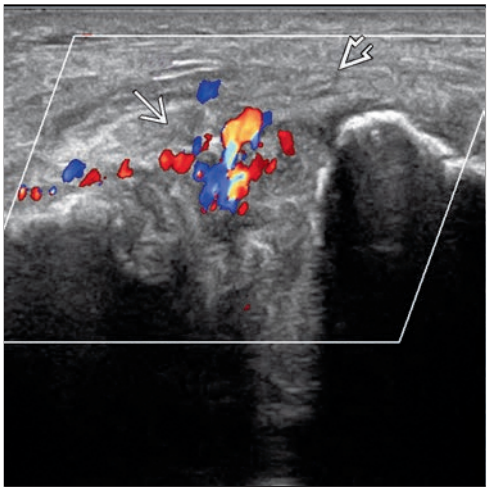
(Left) *Photograph shows a rheumatoid arthritis patient with a 3-month history of painful right sternoclavicular joint swelling. There was also pain, though much less swelling, of the left sternoclavicular joint.* ***(Right)*** *Transverse color Doppler ultrasound of the right sternoclavicular joint in the same patient shows a large amount of hypoechoic synovial thickening with mild hyperemia. No erosion of either the clavicle or the manubrium is present.*



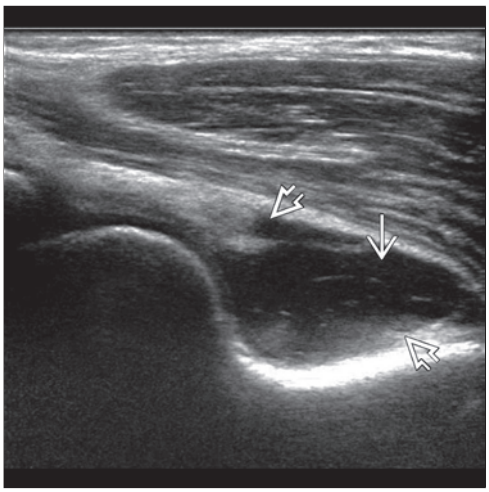


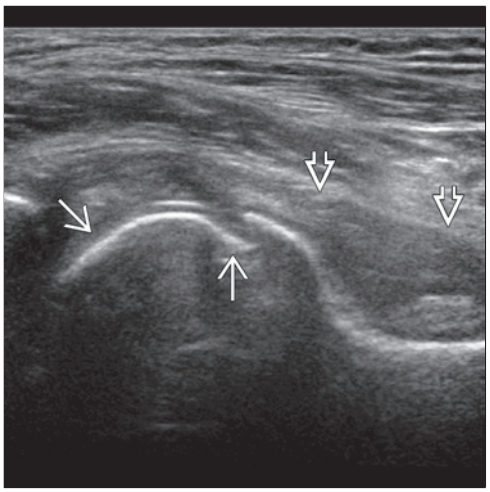
(Left) *Transverse ultrasound in the same patient shows marked widening of the sternoclavicular joint, which is filled with echogenic synovium. This hypertrophied synovium also fills the erosions on the lateral end of the manubrium.* ***(Right)*** *Transverse color Doppler ultrasound in the same patient shows moderate synovial hyperemia, indicative of moderately active synovitis. The periarticular soft tissues are moderately edematous.*

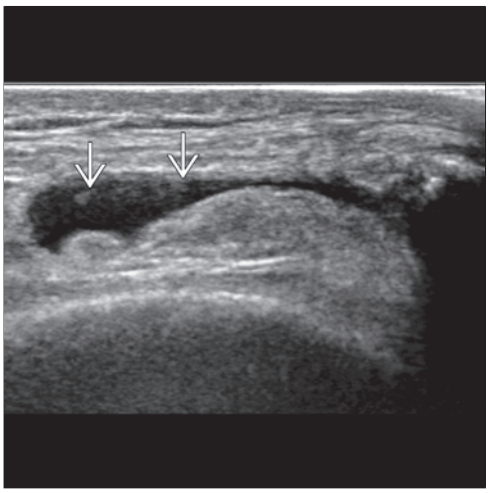


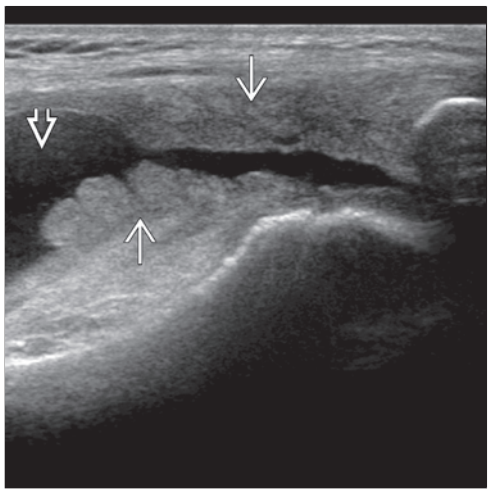


(Left) *Longitudinal ultrasound in a patient with systemic lupus erythematosus and hip pain shows a moderate-sized inflammatory joint effusion with mild synovial proliferation. Aspiration yielded straw-colored, nonpurulent, fluid, which had an increased white cell count though negative on Gram stain and sterile on culture.* ***(Right)*** *Longitudinal ultrasound shows moderate-severity synovial proliferation in a patient with longstanding rheumatoid arthritis and hip pain. There is avascular necrosis with femoral head collapse.*

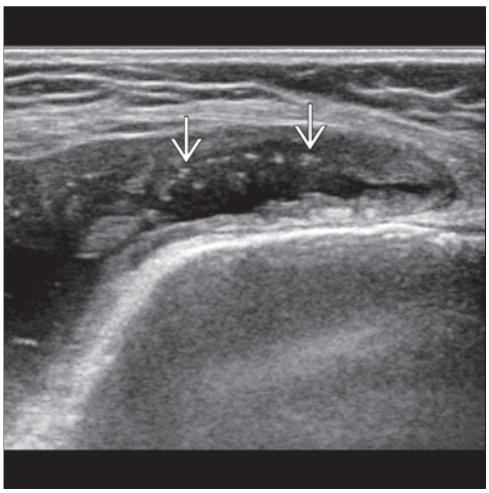


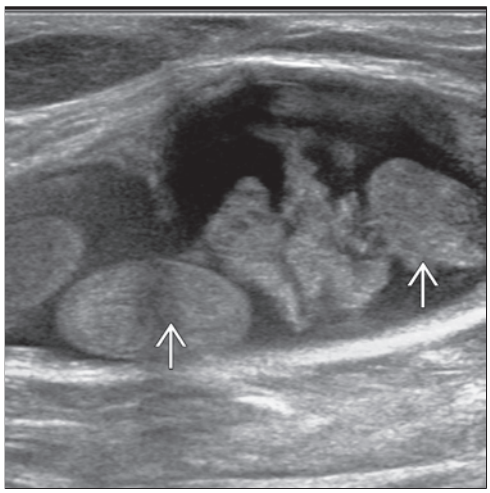




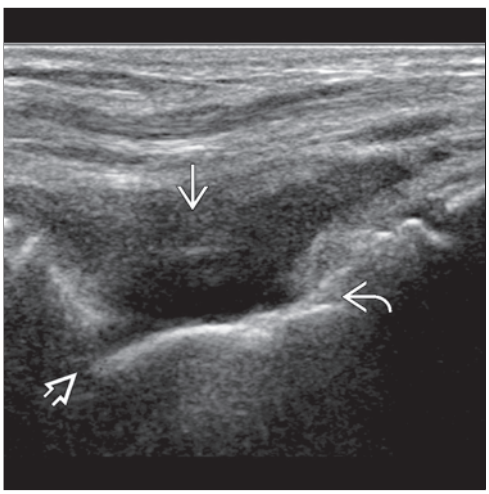


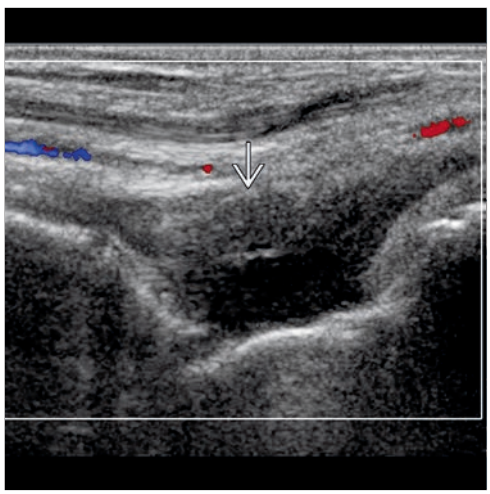
(Left) *Transverse ultrasound in a patient with rheumatoid arthritis shows fluid distension of the lateral patellar recess with frond-like hypoechoic synovial proliferation* ➔. *This hypoechoic synovium is very similar to joint fluid.* ***(Right)*** *Transverse ultrasound of the lateral patellar recess in a patient with rheumatoid arthritis shows more severe, lobulated hyperechoic synovial proliferation* ➔, *which is readily distinguished from joint fluid* ➔.





(Left) *Transverse ultrasound in a rheumatoid arthritis patient with knee pain shows moderately thickened synovium in the medial patellar recess with several small surface echogenic foci* ➔ *due to ether fibrin aggregates or, more likely, crystal aggregates (uric acid or calcium pyrophosphate). Aspiration would help differentiate.* ***(Right)*** *Longitudinal ultrasound of the suprapatellar pouch shows nodular-like synovial proliferation* ➔. *There is no known significance to proliferation type (i.e., smooth, frond-like, lobular, or nodular).*

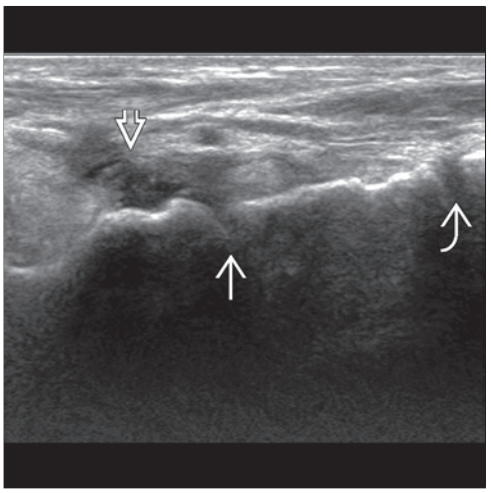


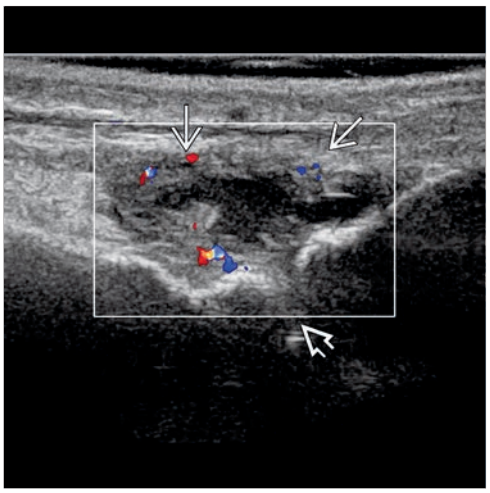


(Left) *Longitudinal ultrasound shows moderate ankle joint* ➔ *capsular distension due to a combination of synovial proliferation* ➔ *and joint fluid. The ankle joint capsule is attached distally to the talar neck* ➔. ***(Right)*** *Longitudinal color Doppler ultrasound in the same patient shows no synovial hyperemia indicative of low-grade synovitis* ➔. *The sizable effusion, however, would point to at least mild synovial activity.*

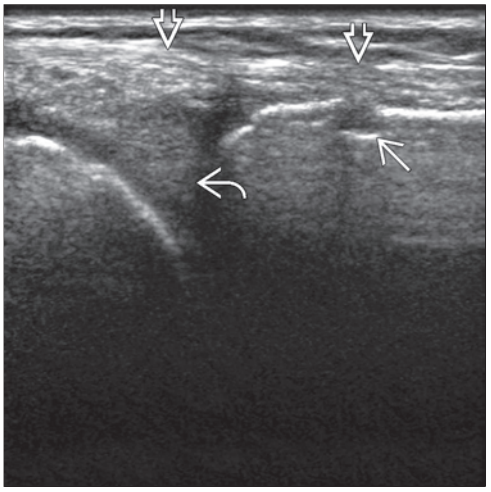
INFLAMMATORY ARTHRITIS

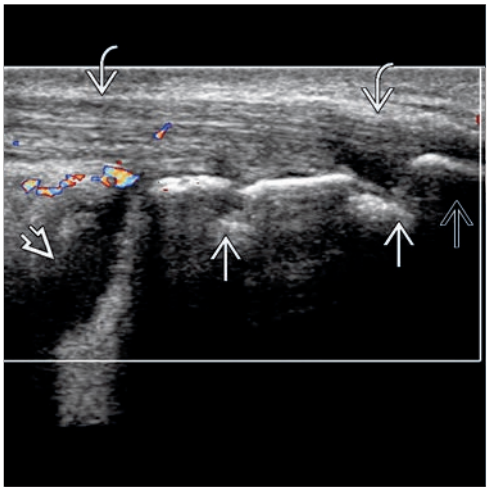
(Left) *Longitudinal ultrasound in a patient with rheumatoid arthritis shows severe talonavicular joint space narrowing* ➔ *with moderate synovial proliferation dorsally* ➔ *and a small joint effusion. The navicular-cuneiform articulation is normal* ➔*.* ***(Right)*** *Longitudinal color Doppler ultrasound in a patient with moderately active rheumatoid arthritis shows mild synovial hyperemia though moderate synovial proliferation and joint distension* ➔ *on the dorsum of the hyperextended 2nd metatarsophalangeal joint* ➔*.*



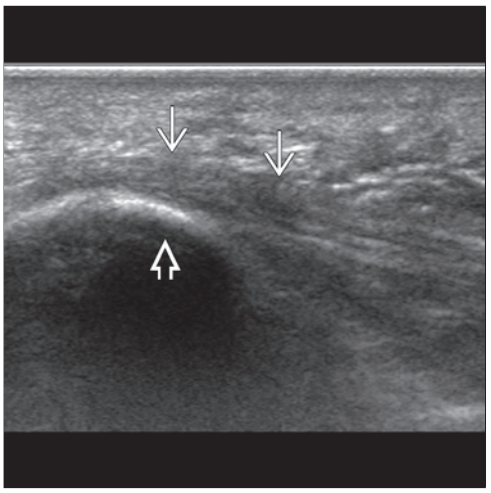


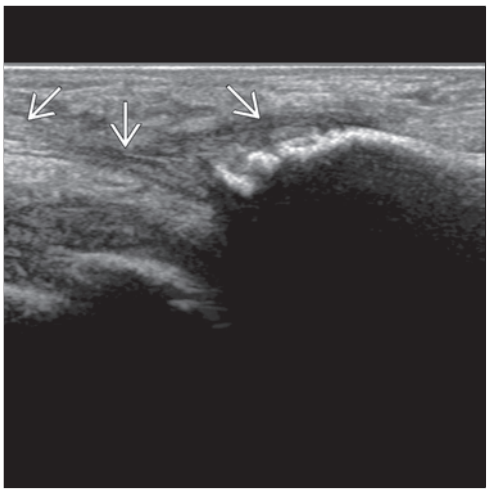
(Left) *Longitudinal ultrasound of the medial aspect of the knee joint in a patient with spondyloarthropathy shows a medium-sized periarticular entheseal erosion* ➔ *deep to the normal medial collateral ligament* ➔*. The medial meniscus* ➔ *is normal.* ***(Right)*** *Longitudinal color Doppler ultrasound in the same patient shows medium-sized entheseal erosions* ➔ *deep to the Achilles tendon* ➔*. There is mild hyperemia alongside a mildly distended retro-Achilles bursa* ➔*. Mild enthesophytosis* ➔ *with cortical hyperostosis is present.*

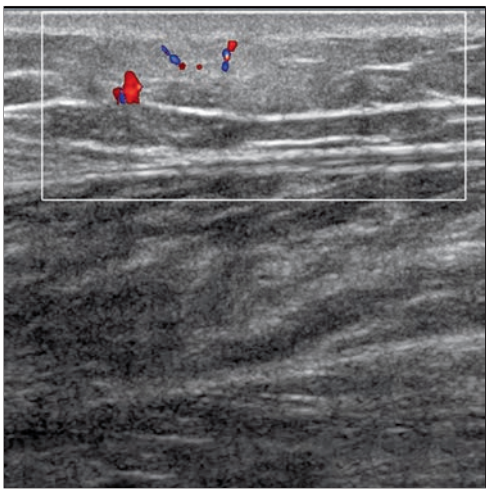


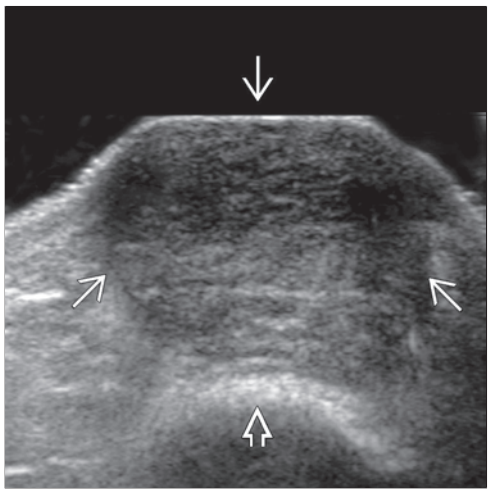


(Left) *Longitudinal ultrasound in an ankylosing spondylitis (AS) patient shows moderate perifascial edema and ill definition of the medial band of the plantar fascia* ➔ *at the medial calcaneal tuberosity* ➔*. Although the fascia is not unduly thickened, this is still consistent with an inflammatory fascitis.* ***(Right)*** *Longitudinal ultrasound in an AS patient shows moderate lateral band plantar fascial thickening* ➔ *at its insertion into the 5th metatarsal base. Moderate cortical irregularity (enthesophytosis) of the insertional area is present.*

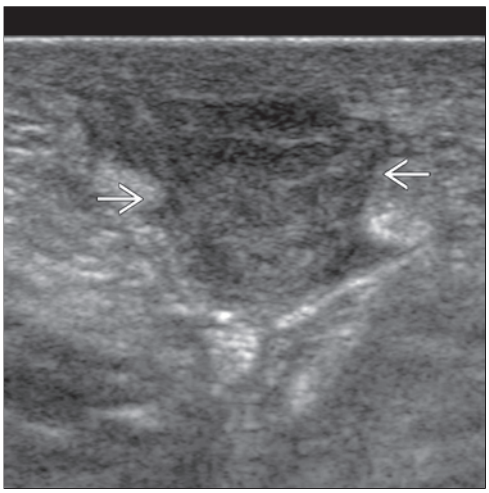


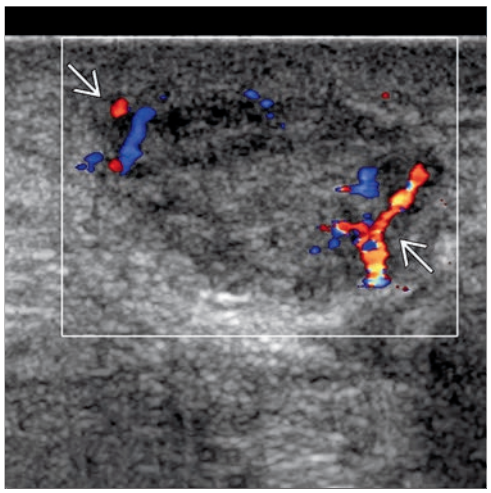




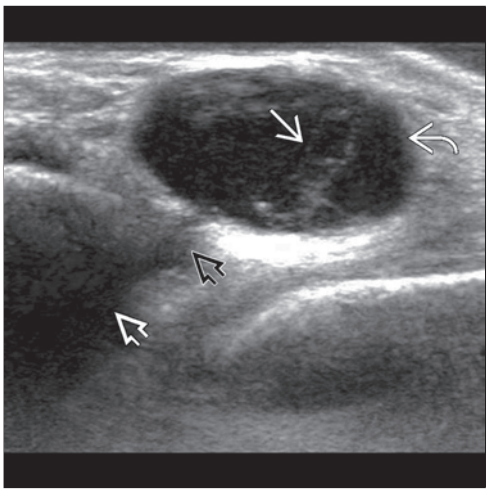


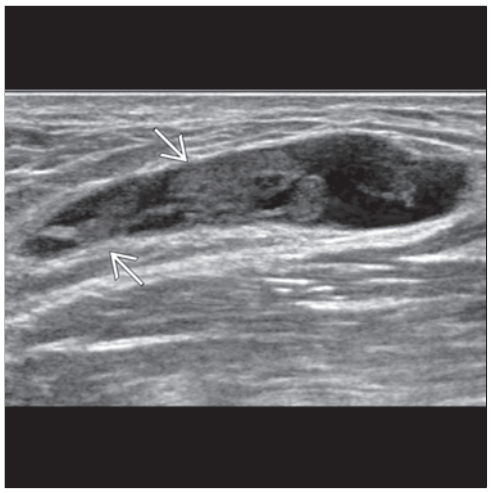
(Left) *Longitudinal ultrasound in a patient with spondyloarthropathy shows subcutaneous panniculitis (with subcutaneous fat edema and hyperemia) on the medial aspect of the distal leg. Panniculitis can occur in patients with inflammatory arthropathy.* ***(Right)*** *Transverse ultrasound shows a typical hypoechoic rounded appearance and subcutaneous location of a rheumatoid nodule. This is located over the olecranon process of the elbow. Mild hyperemia was present on color Doppler imaging.*





(Left) *Transverse ultrasound of the buttock in the same patient shows a more atypical rheumatoid nodule. This rheumatoid nodule has an atypical irregular outline and is located subcutaneously over the ischial tuberosity region (not shown).* ***(Right)*** *Transverse color Doppler ultrasound of the same nodule shows quite typical mild peripheral hyperemia.*





(Left) *Longitudinal ultrasound shows a palmar ganglion in a rheumatoid arthritis patient, which connects via a thin stalk to an inflamed pisiform-triquetral articulation. Inflammatory fibrous-type stranding is present in the ganglion, as inflammatory exudate spreads from the joint to the ganglion.* ***(Right)*** *Longitudinal ultrasound shows thick inflammatory-type exudate within a Baker cyst in a patient with inflammatory knee arthritis. Inflammatory exudate commonly spreads from the knee joint to a Baker cyst.*

GOUT AND PSEUDOGOUT

Key Facts

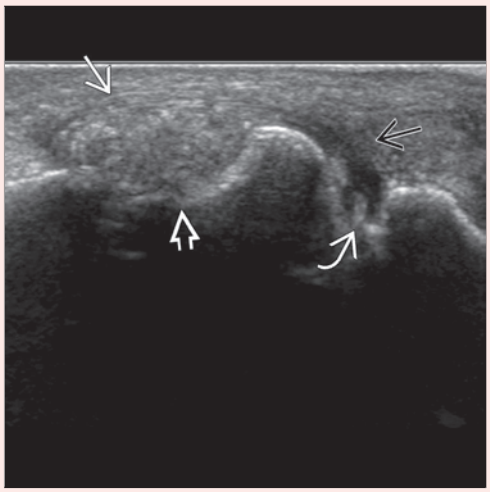
Terminology

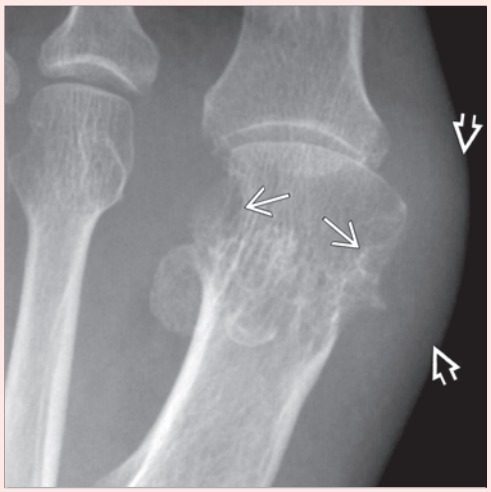
- Inflammatory arthropathy due to urate crystal deposition (gout) or calcium pyrophosphate dihydrate (CPPD) crystal deposition (pseudogout)

Imaging

- **Tophi**
- Soft tophi (hyperechoic with no acoustic shadowing) → hard tophi (hyperechoic with intense acoustic shadowing)
  - Quite well-defined irregular margins with variable hypoechoic halo ("wet clumps of sugar")
  - Multiple grouped tophi are common
- **Tendons & ligaments**
  - Microdeposits with small hyperechoic foci → large hyperechoic foci with intense acoustic shadowing
- **Synovial fluid**
  - Hyperechoic foci or cloudy areas in synovial fluid
    - Fine punctuate echogenicity ("urate sand")
    - Large echogenic aggregates ("snowstorm" appearance)
  - Pseudogout: Fewer echogenic foci in synovial fluid
- **Hyaline (articular) cartilage**
- Gout → thin echogenic band on surface of cartilage ("urate icing")
- Pseudogout → thin echogenic band mid zone of cartilage (CPPD deposition)
  - Hyaline cartilage distribution has high disease specificity
- **Fibrocartilage**
- Pseudogout: Punctuate echogenic foci within hypoechoic fibrocartilaginous disc (wrist) or menisci (knee) due to CPPD deposition
- **Joint aspiration**
  - Send fresh specimen (since crystals dissolved by water, alcohol, or formalin)

(Left) *Longitudinal ultrasound shows typical 1st metatarsophalangeal joint (MTPJ) gouty arthritis. The soft tophus causes marginal erosion of the metatarsal head. A small joint effusion is present in the MTPJ with echogenic gouty crystal aggregates.* ***(Right)*** *Anteroposterior radiograph of the same patient shows soft tissue swelling and marginal erosions. The tophi are largely noncalcified and not clearly seen.*





(Left) *Axial NECT of the same patient shows hyperdense calcified tophi. CT is more sensitive than radiography at revealing gouty tophi. There are marginal erosions deep to the tophi.* ***(Right)*** *Axial T1WI MR of the same patient shows the isointense (to muscle) tophi and marginal erosions. Dual-energy CT (if available) is better than MR or ultrasound at quantifying gouty tophi volume for monitoring response to treatment.*





GOUT AND PSEUDOGOUT

TERMINOLOGY

Synonyms
- Gouty arthropathy, crystalline arthropathy, metabolic arthritis, tophaceous gout, podagra, gouty tophi

Definitions
- Inflammatory arthropathy due to urate crystal deposition (gout) or calcium pyrophosphate dihydrate (CPPD) crystal deposition (pseudogout)

IMAGING

General Features
- Best diagnostic clue
  - Identification of echogenic foci (crystals) in joint or soft tissues
- Location
  - Gout: 1st metatarsophalangeal joint (podagra) (50%) > ankle > midfoot > knee > wrist
    - Helix of ear, olecranon bursa, tendons (especially patellar and triceps), knee and ankle ligaments
  - Pseudogout: Any joint especially knee, wrist, scapho-trapezium-triquetral joints
    - Extrachondral involvement (synovium, tendons, ligaments, soft tissues) is less common in pseudogout than in gout
- Size
  - Gouty tophi range from few mm to 5 cm
- Morphology
  - Monoarticular swelling → deforming polyarthropathy
    - Tophi lead to hard discrete nodules in subcutaneous, para-articular, & other tissues

Radiographic Findings
- Eccentric soft tissue hyperdense swelling ± calcification
  - 1/3 of tophi are calcified
- Asymmetrical arthropathy
  - Absence of osteopenia
  - Joint space preserved until late
  - Marginal erosions with overhanging edges and thin sclerotic edge
    - Larger than erosions of rheumatoid arthritis

CT Findings
- Dual-energy CT can quantitatively identify urate deposits
  - Useful for monitoring treatment

MR Findings
- T1WI
  - Tophi: Well-defined masses, isointense to muscle
- T2WI
  - Tophi: Low to high signal intensity
    - Variable intensity reflects amount of urate deposition, edema, and maturity of granulation tissue
    - Relative absence of bone marrow edema suggests pathophysiology of erosions in gout differ from other inflammatory arthropathies
- T1WI C+
  - Tophi: Honeycomb-like heterogeneous to near-homogeneous enhancement
    - Honeycomb appearance is due to avascular urate surrounded by vascularized granulation tissue

Ultrasonographic Findings
- More accurate than clinical examination or radiography at detecting gouty tophi
- **Tophi**
  - Soft tophi (hyperechoic with no acoustic shadowing) → hard tophi (hyperechoic with intense acoustic shadowing)
    - Depends on compactness of crystals within tophaceous deposits
  - Quite well-defined irregular margins with variable hypoechoic halo ("wet clump of sugar")
  - Multiple grouped tophi are common
- **Tendons (and ligaments)**
  - Ranges from microdeposits with small hyperechoic foci within tendon to large hyperechoic foci with intense acoustic shadowing
    - Fibrillar pattern is disrupted, tendon is stretched and displaced
    - ± tendon rupture (uncommon)
    - Acoustic shadowing with larger (> 5 mm) masses
- **Synovial fluid**
  - Gout → variable appearance of joint fluid
    - Hyperechoic foci in synovial fluid ("hyperechoic aggregates")
      - Fine punctuate echogenicity ("urate sand")
      - Large echogenic aggregates ("snowstorm" appearance)
    - Hyperechoic cloudy areas
  - Pseudogout produces fewer echogenic aggregates in joint fluid
- **Hyaline (articular) cartilage**
  - Gout: Thin echogenic band on surface of cartilage ("urate icing")
    - No acoustic shadowing
  - Pseudogout: Thin echogenic band mid zone of cartilage (CPPD deposition)
    - No acoustic shadowing
- **Fibrocartilage**
  - Pseudogout → punctuate echogenic foci within hypoechoic fibrocartilaginous disc (wrist) or menisci (knee) due to CPPD deposition
- **Bone**
  - Marginal erosions
    - Invariably associated with overlying tophus

Imaging Recommendations
- Best imaging tool
  - Ultrasound to inspect joint and adjacent tissues and to aid joint aspiration
    - Ultrasound signs are often specific enough to make diagnosis without joint aspiration
- Protocol advice
  - Assess all aspects of joint (cartilage, fluid, synovium) and periarticular structures (ligaments, tendons, bone)
  - ± synovial fluid aspiration for analysis by polarizing light microscopy (sensitivity: 84%, specificity: 100%)
    - Only small amount of fluid is required for analysis
    - Send fresh specimen (since crystals are dissolved by water, alcohol, or formalin)
    - Urate crystals: Needle-like, negatively birefringent

GOUT AND PSEUDOGOUT

    - CPPD crystals: Rod-like, positively birefringent
  - Urate and CPPD crystals may coexist
  - Also send fluid for Gram stain, culture, and cell count

DIFFERENTIAL DIAGNOSIS

Rheumatoid Nodule
- Hypoechoic, well defined ± hyperemia
  - No echogenic foci
  - Typical location (over bony prominences)

Rheumatoid Arthritis
- Symmetrical polyarthropathy
- Proteinaceous aggregates of inflammatory arthropathy less echogenic than crystal aggregates
- Absence of crystals on synovial fluid analysis

Septic Arthritis
- Distinction from acute gout can be difficult
  - Septic arthritis and crystal arthropathy may coexist
  - Synovial fluid analysis helpful

PATHOLOGY

General Features
- Etiology
  - Genetic
  - Diet ("disease of kings")
  - Diabetes, thiazide diuretics, renal impairment
- Associated abnormalities
  - Hypertension, diabetes mellitus, metabolic syndrome, abdominal obesity, hyperlipidemia
  - Renal stones (1,000x increased incidence)
    - Pure uric acid stones (80%); mixed stones i.e., calcium oxalate or calcium phosphate deposition on uric acid core (20%)
- Uric acid = end product of purine catabolism
  - ↓ excretion of uric acid in urine (90% cases)
  - ↑ production of uric acid (10% cases)
- Only a fraction of patients with hyperuricemia develop clinical gout
  - Ultrasound is helpful to diagnose subclinical gouty arthritis in hyperuricemic individuals
- Urate solubility is affected by factors other than concentration
  - Cold, pH, tissue composition and turnover
  - Uric acid preferentially deposits in synovium, around joints, tendons, ligaments
- Urate crystals are coated with apolipoprotein E or B
  - Protein coating may stop crystals from triggering inflammation
  - Immunoglobulins bind to bare areas on crystals and initiate phagocytosis by neutrophils
  - Exposure of bare areas on crystals (flux in uric acid level or trauma) may trigger acute inflammation

Gross Pathologic & Surgical Features
- Tophi; multilobulated locules containing white, chalky material

Microscopic Features
- Multicentric urate crystals surrounded by vascularized granulation tissue and inflammatory infiltrate

CLINICAL ISSUES

Presentation
- Most common signs/symptoms
  - Acute monarticular arthritis (90%)
    - Severe inflammation reaching maximum intensity in 8-12 hours
- Other signs/symptoms
  - Gouty tophi
    - Arthritis usually precedes development of tophi
    - Tophi slowly enlarge over years

Demographics
- Age
  - Peak onset = 30-50 years (males), 50-70 years (females)
    - Earlier with renal insufficiency or genetic predisposition
- Gender
  - Male:female = 9:1 in gout
    - Estrogen is mildly uricosuric
    - Gout more common in postmenopausal women
  - Male:female = 1.5:1 in pseudogout
- Epidemiology
  - 1% of general population

Natural History & Prognosis
- Acute attack resolves spontaneously in < 2 weeks if untreated
  - Joint is normal between attacks (early disease)
  - → polyarticular involvement with attacks becoming less intense, more frequent, & lasting longer
  - → chronic polyarthropathy
  - If serum urate levels are lowered consistently below 6 mg/dl, reduction in urate crystals can be seen on ultrasound
- Gouty nephropathy

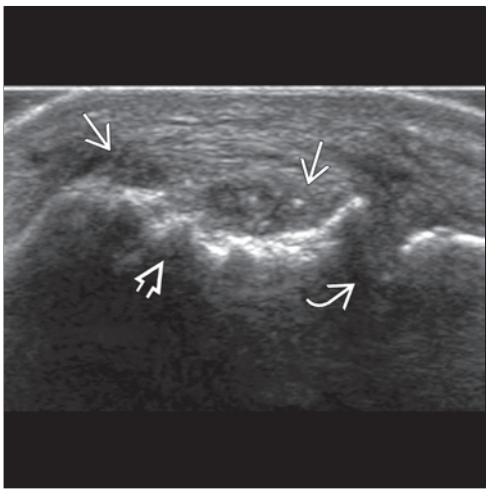
Treatment
- Limiting acute attack
  - Rest
  - Nonsteroidal anti-inflammatory agents
- Prevention or reversal of crystal deposition
  - Diet modification
  - Weight reduction
  - Drug therapy: Allopurinol, probenecid, or colchicine
- Surgery
  - Excision of tophi (cosmetic, chronically discharging)

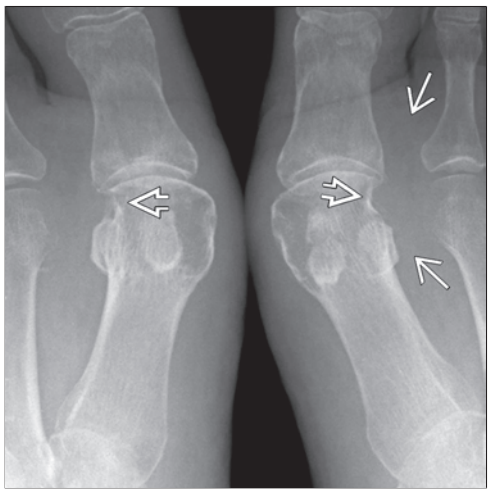
DIAGNOSTIC CHECKLIST

Consider
- Ultrasound evaluation should include assessment of synovial fluid, articular cartilage, bone, tendons, ligaments, and soft tissue tophi
  - Distinction between gout and pseudogout rests on site of crystal deposition and synovial fluid analysis

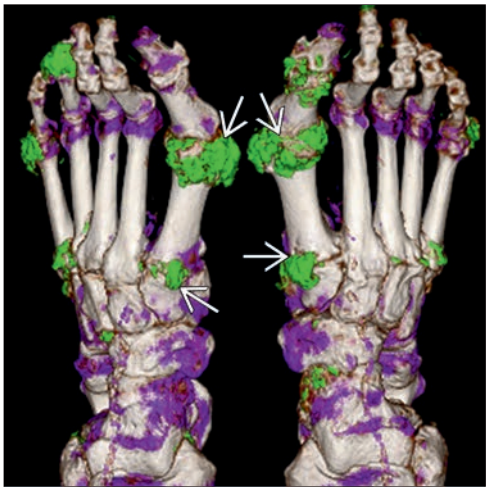
SELECTED REFERENCES

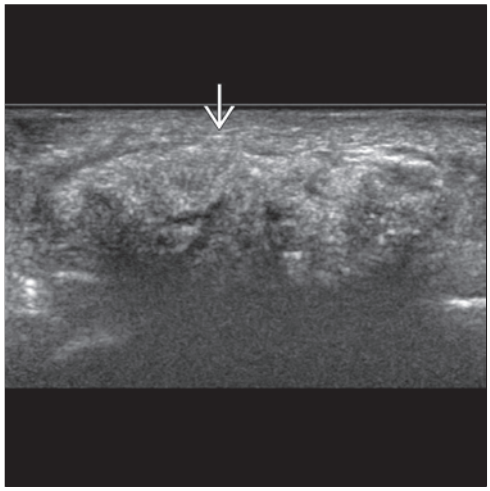
1. Girish G et al: Imaging appearances in gout. Arthritis. 2013:673401, 2013
2. Dalbeth N et al: Imaging of gout: an overview. Best Pract Res Clin Rheumatol. 26(6):823-38, 2012



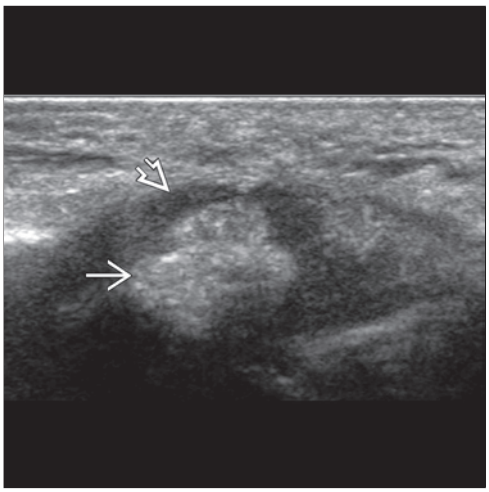


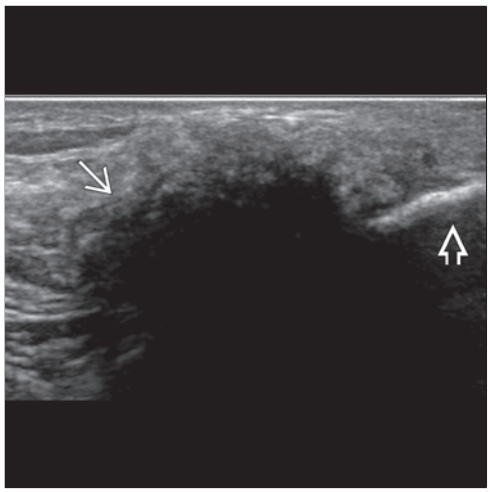
(Left) *Longitudinal ultrasound shows a soft tophus near the 1st metatarsophalangeal joint (MTPJ) with marginal erosion of the metatarsal head. A small MTP joint effusion is present with tiny echogenic "urate sand" within the synovial fluid.* ***(Right)*** *Anteroposterior radiograph of the same patient shows soft tissue swelling and marginal erosions of both MTP joints. Symptoms were only present on the right side.*





(Left) *Three-dimensional reformatted dual-energy CT image shows multiple urate deposits (colored green) in both feet. Total urate volume can be quantified by DECT using an automated volume estimation method. (Courtesy P. Munk, MD.)* ***(Right)*** *Transverse ultrasound of the dorsum of the foot shows gouty tophus with diffuse increased echogenicity and moderate posterior shadowing. Almost the full depth of the tophus can be seen, but the deeper structures cannot be appreciated.*

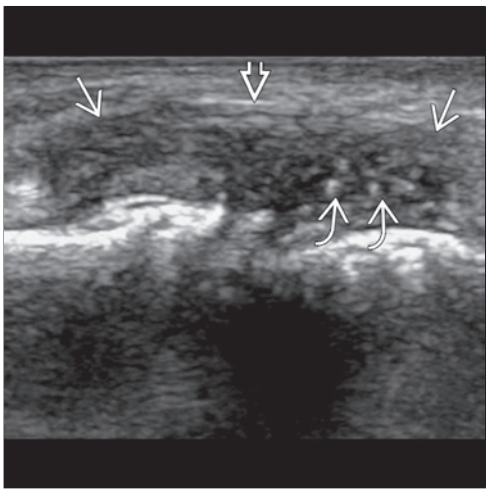


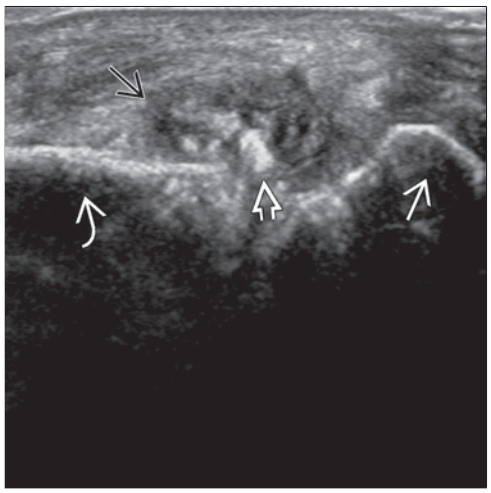


(Left) *Transverse ultrasound of the volar aspect of the wrist shows a moderately hard gouty tophus just proximal to the tunnel inlet. There is a hyperechoic central area with a quite well-defined hypoechoic rim of granulation tissue ("lump of wet sugar" appearance).* ***(Right)*** *Longitudinal ultrasound shows a very hard gouty tophus overlying the anterior tibial tuberosity. Neither the internal composition of the tophus nor the structures deep to the tophus can be appreciated. The tibial shaft is shown.*

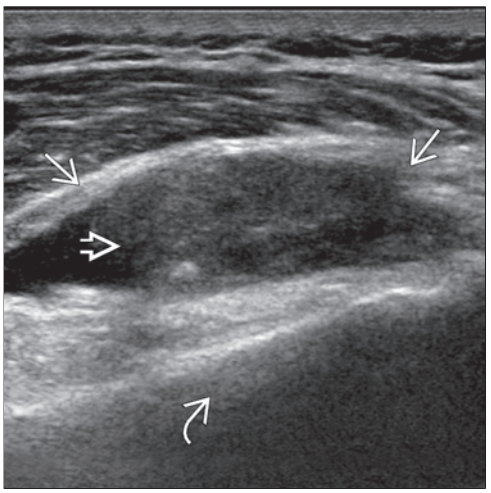
GOUT AND PSEUDOGOUT

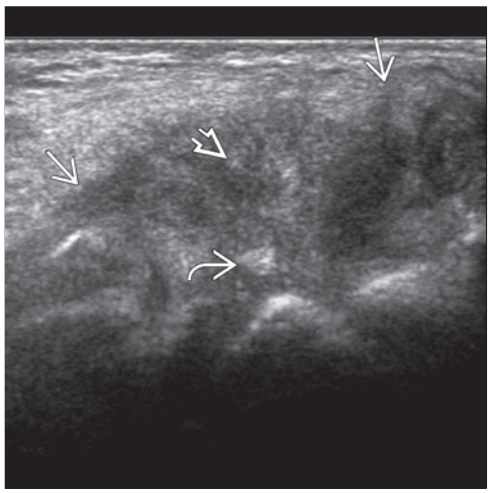
(Left) *Longitudinal ultrasound of the knee shows synovial proliferation and fluid on the medial aspect of the knee joint beneath the medial collateral ligament. There are fine punctuate echogenic foci present, compatible with "urate sand".* ***(Right)*** *Transverse ultrasound in the same patient shows joint distension with large gouty crystal aggregates anterior to the articulation between the proximal tibia and the fibula.*



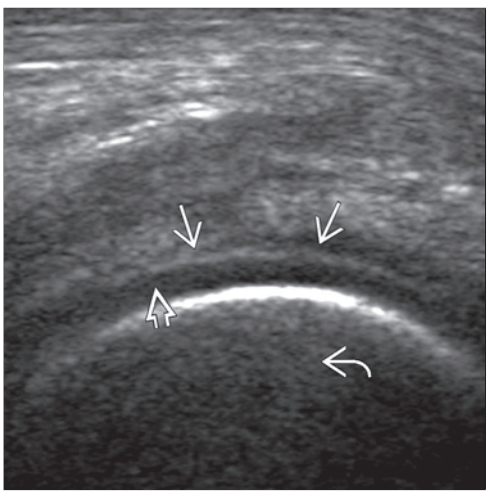


(Left) *Longitudinal ultrasound of the knee in a patient with gout shows a moderate-sized joint effusion containing fine echogenic aggregates. The distal femur is shown.* ***(Right)*** *Oblique ultrasound of the anterolateral aspect of the ankle joint shows a large joint effusion containing fine echogenic fluid, "urate sand" and a larger echogenic crystal aggregate. In the right clinical setting, it is not always necessary to perform joint aspiration to confirm gout.*



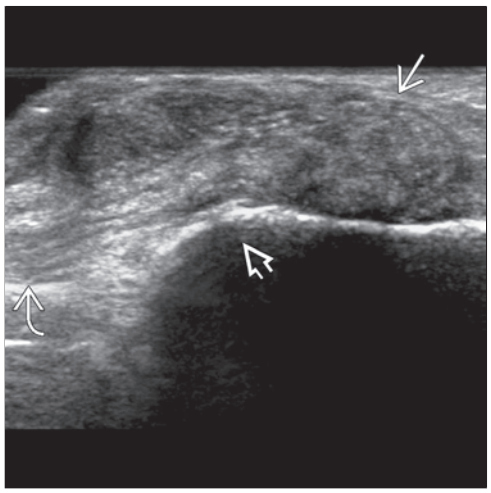


(Left) *Longitudinal ultrasound of the knee shows a thin echogenic band due to urate deposition ("urate icing") on the surface of the hyaline cartilage of the femoral condyle. This pattern of crystal deposition is quite specific for gout.* ***(Right)*** *Oblique ultrasound of the same patient shows a large, soft gouty tophus on the lateral aspect of the distal femur. The internal structure of the tophus as well as the bone deep to the tophus can be fully appreciated.*

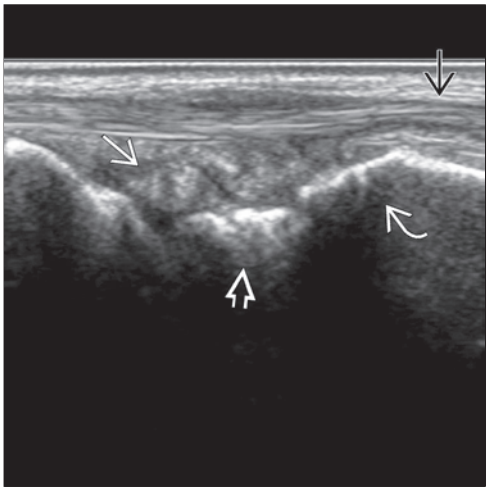


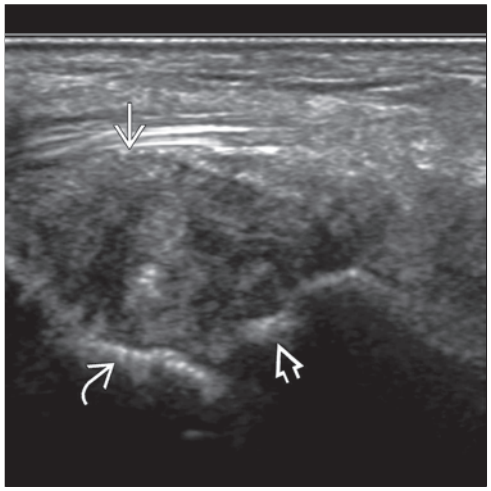






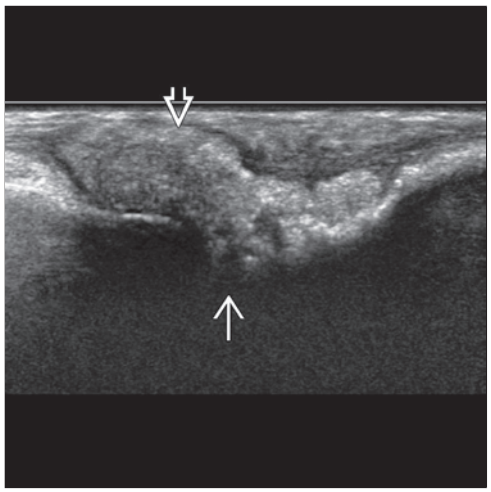
(Left) *Clinical photograph shows a patient with gout with swelling and mild redness on the lateral part of the midfoot/forefoot junction.* ***(Right)*** *Oblique ultrasound of the dorsolateral foot in the same patient shows a soft tophus overlying the 5th metatarsal base at the site of insertion of the peroneus brevis tendon.*





(Left) *Longitudinal ultrasound shows gouty arthritis on the dorsoulnar aspect of the wrist joint. There are small echogenic foci in the joint ("snowstorm" appearance) with urate deposits on the articular disc surface. The ulnar head and extensor carpi ulnaris tendon are normal.* ***(Right)*** *Longitudinal ultrasound of the same patient shows echogenic synovial proliferation/joint fluid with joint space narrowing between the scaphoid and the distal radius.*



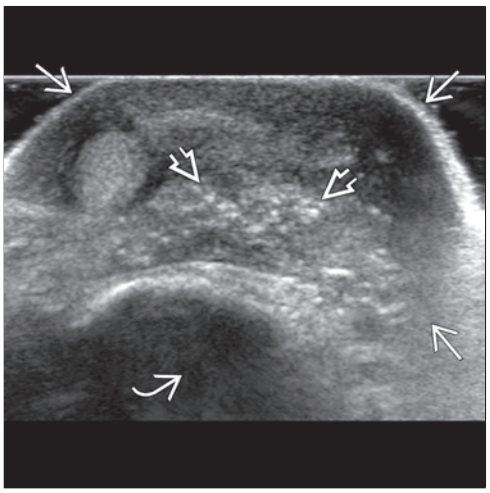


(Left) *Dorsoplantar radiograph shows the foot in an elderly woman with no known gout. Due to recent swelling and radiographic abnormality, she was referred with a suspected chondrosarcoma.* ***(Right)*** *Longitudinal ultrasound of the same patient shows severe destruction of the 3rd metatarsophalangeal joint with the joint capsule distended by finely punctuate echogenic fluid ("urate sand"). This is entirely consistent with a gouty arthropathy. The appearances are not those of malignancy.*

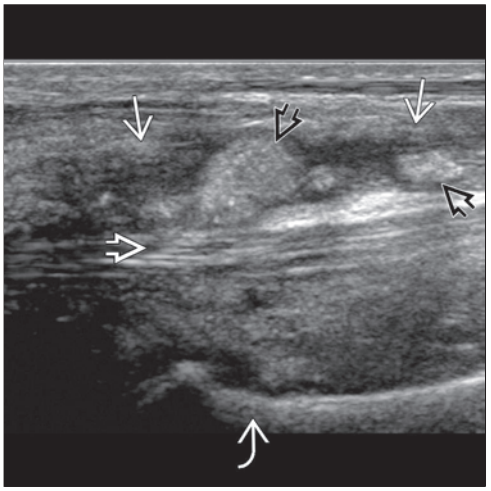
GOUT AND PSEUDOGOUT

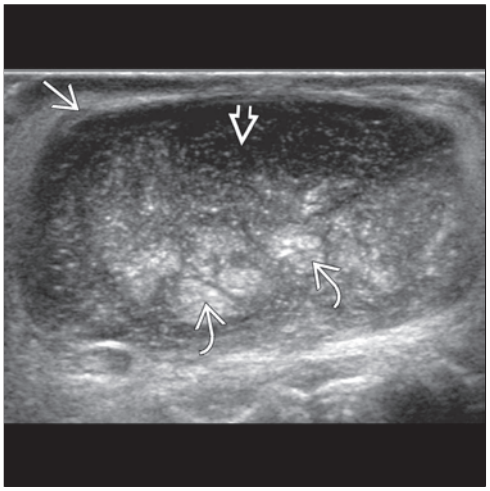
(Left) *Clinical photograph of patient with known gout shows swelling and redness* ➔ *at the posterior aspect of the elbow, consistent with olecranon bursitis.* ***(Right)*** *Transverse ultrasound of the elbow shows gouty olecranon bursitis* ➔ *superficial to the olecranon* ➔*. The bursa is distended with finely echogenic fluid ("urate sand")* ➔.



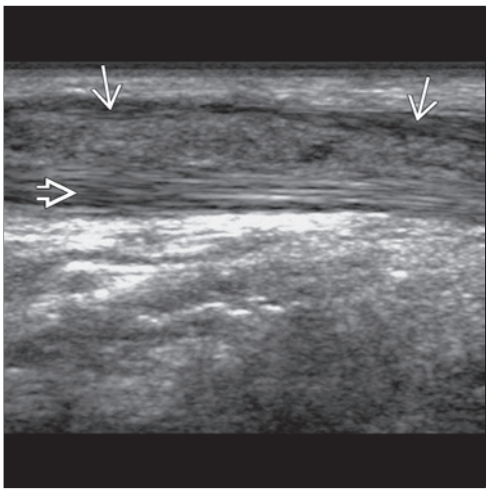


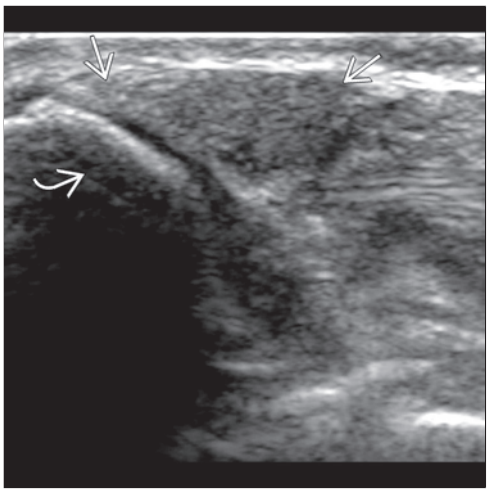
(Left) *Longitudinal ultrasound of the hand shows severe gouty flexor tenosynovitis. The tendon sheath* ➔ *is distended with fluid and large crystal aggregates* ➔*. The flexor tendon* ➔ *and metacarpal bone* ➔ *are normal.* ***(Right)*** *Transverse ultrasound shows severe gouty flexor tenosynovitis of the wrist. The tendon sheath is severely distended* ➔ *with fine echogenic fluid ("urate sand")* ➔*. The flexor tendons* ➔ *are poorly defined, with features of intratendinous urate deposition.*

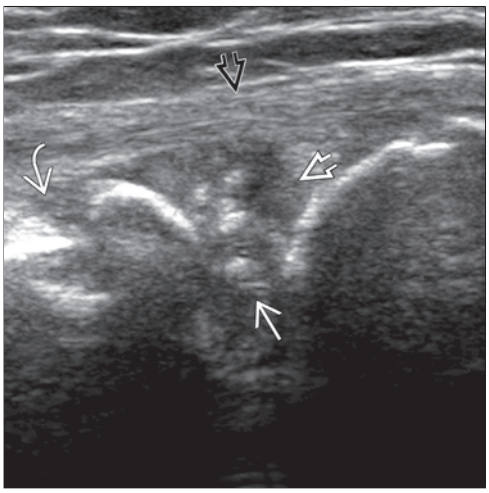


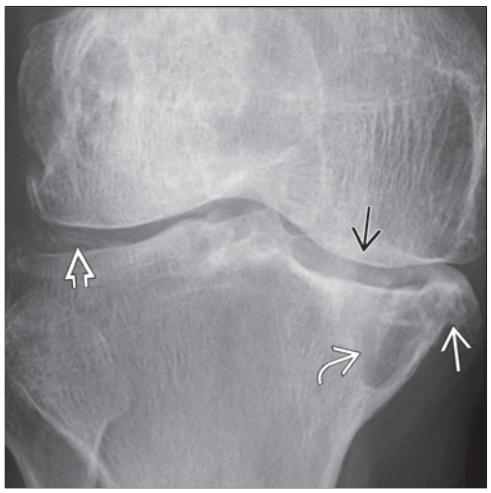


(Left) *Longitudinal ultrasound shows gouty tenosynovitis of the anterior tibialis tendon. The tendon sheath is eccentrically distended with finely echogenic urate deposition* ➔*. The tendon* ➔ *is normal. This eccentric deposition allows distinction between solid and more liquefied forms of urate deposition.* ***(Right)*** *Transverse ultrasound shows a soft tophus deposit* ➔ *in the flexor retinaculum of the tarsal tunnel close to the tibial* ➔ *attachment.*

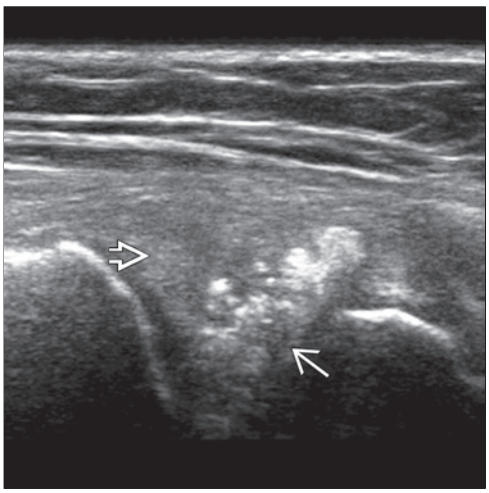


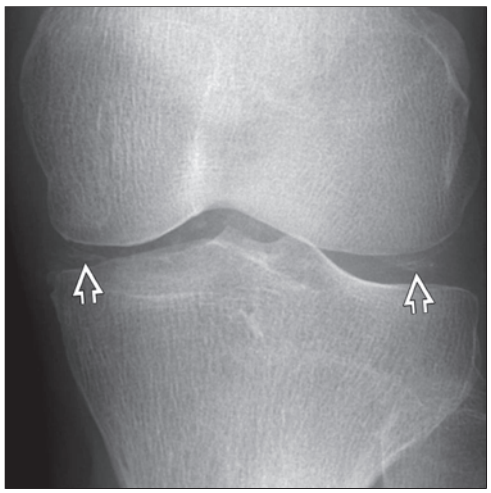




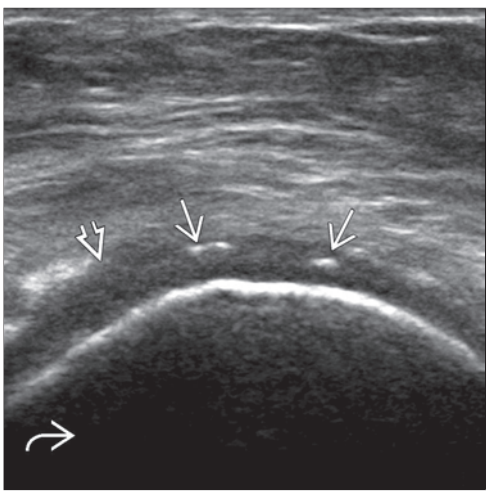


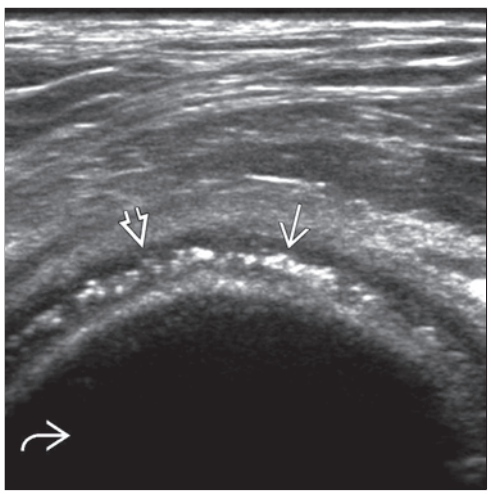
(Left) *Longitudinal ultrasound of the knee shows echogenic foci (CPPD deposition) within the lateral meniscus. The lateral collateral ligament is normal. There is marginal bony erosion.* ***(Right)*** *Anteroposterior radiograph of the same patient shows chondrocalcinosis of the lateral meniscus. There are features of quite severe osteoarthritis with marginal osteophytosis, joint space narrowing, and a large subchondral cyst.*





(Left) *Longitudinal ultrasound of the knee shows echogenic foci due to CPPD deposition in the medial meniscus.* ***(Right)*** *Anteroposterior radiograph of the same patient shows moderate chondrocalcinosis of both the medial and lateral menisci. Calcium pyrophosphate deposits centrally in the menisci, while urate deposits initially on the surface of the menisci.*





(Left) *Longitudinal ultrasound of the knee shows several discrete echogenic foci due to CPPD deposition in the mid zone of the articular cartilage on the posterior aspect of a femoral condyle.* ***(Right)*** *Longitudinal ultrasound of the knee shows a quite confluent echogenic band due to CPPD deposition in the mid zone of the articular cartilage of the medial femoral condyle posteriorly. This pattern of crystal deposition is quite specific for CPPD disease.*

DEVELOPMENTAL HIP DYSPLASIA

Key Facts

Imaging

- Shallow acetabulum ± subluxation of femoral head
- Ultrasound is useful before 6 months of age
- Normal hip
  - Capsular laxity: > 50% bony coverage femoral head at rest, with < 50% bone coverage on stress examination or normal movement
- Subluxation: < 50% bony coverage at rest
- Dislocation: Femoral head lies completely outside of bony acetabulum at rest
- Modified Graf staging
  - Type Ia = mature hip, angular bony promontory, α > 60˚, β < 55˚
  - Type Ib = mature hip, roundish bony promontory, α > 60˚, β < 55˚
  - Type IIa = physiologic immaturity < 3 months, α = 50-60˚, β = 55-77˚
  - Type IIb = immaturity > 3 months, α = 50-60˚, β = 55-77˚
  - Type IIc = critical hip, subluxation, α = 43-49˚, β > 77˚
  - Type III = dislocated hip, α < 43˚
  - Type IV = dislocated hip, inverted labrum, α < 43˚

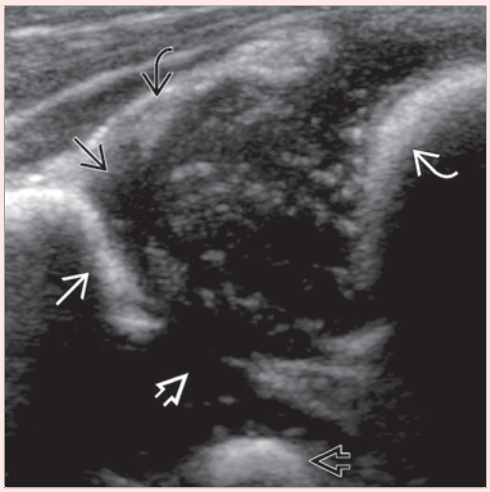
Top Differential Diagnoses

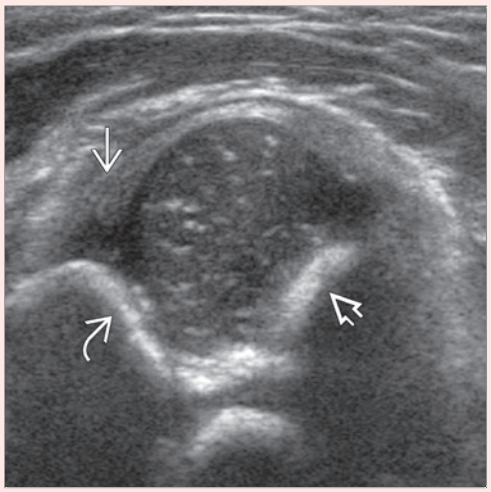
- Physiologically immature hip in neonate or premature baby

Diagnostic Checklist

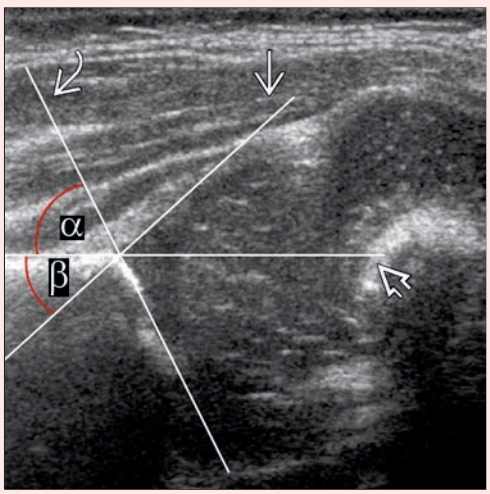
- Key to diagnosis rests on obtaining correct coronal (longitudinal) view
- Be clear with respect to definitions of capsular laxity, subluxation, and dislocation
  - Useful to have these definitions written on ultrasound report
- If in doubt, repeat ultrasound in 2-4 weeks

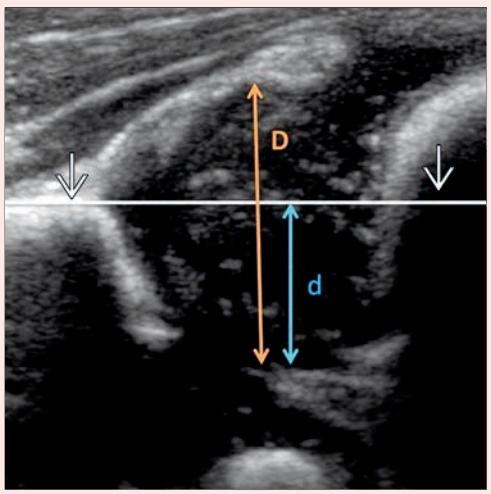
(Left) *Longitudinal coronal ultrasound shows a standard view of a normal hip. This view includes the osseous acetabular roof, cartilaginous acetabular roof, acetabular labrum, triradiate cartilage, ischium, and ossified femoral metaphysis.* ***(Right)*** *Transverse ultrasound of a normal hip shows the femoral head well centered within the acetabulum. The anterior pillar of the acetabulum, acetabular labrum, femoral metaphysis, and gluteal muscle are shown.*





(Left) *Longitudinal coronal ultrasound shows a standard view of a normal hip. Note the lines along the ilium, acetabular roof, between the acetabular promontory and the tip of acetabular labrum, and the α and β angles formed by the intersection of these lines.* ***(Right)*** *Longitudinal ultrasound scan shows a standard coronal view of a normal hip with a well-covered femoral head. The portion of the femoral head diameter (D) covered by bone acetabulum (d) is > 50% (D/d > 50%). Note the iliac line.*





DEVELOPMENTAL HIP DYSPLASIA

TERMINOLOGY

Abbreviations
- Developmental dysplasia of hip (DDH)

Synonyms
- Congenital dysplasia of hip (CDH)

Definitions
- Underdevelopment of acetabular component of hip joint

IMAGING

General Features
- Best diagnostic clue
  - Shallow acetabulum ± subluxation of femoral head
- Morphology
  - Ranges from shallow acetabulum to complete dislocation with false acetabulum
    - Secondary hypoplasia of femoral head

Ultrasonographic Findings
- Most useful between birth and 6 months
- Both static and dynamic evaluation
- Coronal view ("egg in spoon" view)
  - Most important image
  - Obtained from lateral approach with hip at ~ 20° of flexion; infant in decubitus (or supine) position
  - Align transducer 10-15° obliquely (usually posteriorly) from coronal plane to obtain straight iliac line
  - Obtain single image showing deepest part of acetabulum, triradiate cartilage, center of femoral head, straight iliac contour
    - Position too anterior → false-positive result
  - Gas can be found within normal hip
- Transverse view ("ice cream cone" view)
  - Shows femoral head overlying triradiate cartilage
- Useful to continue screening hip during active movement if child is restless
  - Will give indication as to stability of hip during normal movement
- Dynamic testing: Apply Barlow maneuver (i.e., posterior force on adducted and flexed hip)
  - Attempt to displace femoral head from acetabulum during real-time imaging
  - Lack of infant relaxation could hinder or prevent acquisition of optimal stress view and can produce false-negative examination
  - Overall, however, nonstress views provide more information than stress views
- 3 lines drawn on coronal view to assess acetabular morphology
  - Line along straight contour of ilium (iliac line)
  - Line along osseous acetabular roof
  - α angle is measured at intersection between iliac line and line along osseous acetabular roof
    - α angle is acetabular angle
    - Reflects steepness of acetabular roof
  - Line from promontory to tip of labrum
  - β angle is measured at intersection between iliac line and line from acetabular promontory to tip of labrum
    - Represents elevation of acetabular labrum
- Acetabular bony coverage
  - Portion of femoral head contained within bony acetabulum
  - Center of femoral head relative to iliac straight line
- Normal hip
  - Sharp edge to ossified acetabular roof (promontory)
    - Roundish anterior acetabular rim can be physiological and is often seen in immature hips
  - Should have > 50% of femoral head covered by bony acetabulum ("bony coverage")
    - Important and easy to comprehend measurement
  - Normal α angle > 60°, β angle < 55°
    - α angle is more critical than β angle
- Capsular laxity: > 50% bony coverage femoral head at rest, < 50% bone coverage on stress examination or active movement
- Subluxation: < 50% bony coverage at rest
  - Some centers define subluxation as < 33% bony coverage and 33-50% as indeterminate
- Dislocation: Femoral head lies completely outside of bony acetabulum at rest
- Modified Graf staging
  - Type Ia = mature hip, angular bony promontory, α > 60°, β < 55°
  - Type Ib = mature hip, roundish bony promontory, α > 60°, β < 55°
  - Type IIa = physiologic immaturity < 3 months, α = 50-60°, β = 55-77°
  - Type IIb = immaturity > 3 months, α = 50-60°, β = 55-77°
  - Type IIc = critical hip, subluxation, α = 43-49°, β > 77°
  - Type III = dislocated hip, α < 43°
  - Type IV = dislocated hip, inverted labrum, α < 43°

Radiographic Findings
- Radiography
  - Hip dysplasia associated with relatively shallow acetabulum with slanting roof and relatively small superolaterally placed femoral head
  - Hilgenreiner line links tops of both triradiate cartilages
    - Femoral metaphysis should lie below Hilgenreiner line
  - Perkin line is perpendicular to Hilgenreiner line through lateral margin of bony acetabulum
    - Femoral capital epiphysis should lie within inner lower quadrant of intersection between Perkin and Hilgenreiner lines
  - Acetabular index is angle between acetabular roof and Hilgenreiner line
    - 30-32° in newborn; ↓ in older children

MR Findings
- T2WI
  - Inverted limbus of acetabular roof is best seen on coronal images
    - Hypertrophy of hypointense ligamentum teres and fibrofatty pulvinar
    - Hypointense interposed iliopsoas tendon

Imaging Recommendations
- Best imaging tool
  - Ultrasound is useful up to 6 months of age

DEVELOPMENTAL HIP DYSPLASIA

- Limited at 6-9 months and not useful thereafter
- Protocol advice
  - 0-3 months: Linear transducer ≥ 10 MHz or 7.5 MHz (if fat baby)
  - Lateral decubitus (or supine) position with standard orthogonal views
    - Hip in slightly flexed position
  - Ensure that definitions of capsular laxity, subluxation, and dislocation are clear to those interpreting the ultrasound result
    - Useful to have these definitions written on ultrasound report

DIFFERENTIAL DIAGNOSIS

Physiological Immature Hip
- In neonate or premature baby

PATHOLOGY

General Features
- Etiology
  - Laxity of joint capsule
  - Inadequate contact between acetabulum and femoral head
- Relevant anatomy
  - Osseous acetabulum is formed by portions of ilium, ischium, and pubis
    - These osseous elements unite at triradiate cartilage (growth cartilage)
  - Echogenic fibrocartilage at edge of cartilaginous roof is the true acetabular labrum
  - Ossification centre of femoral head appears on ultrasound before it appears radiographically (6th-8th week)
  - Acetabulum is particularly susceptible to remodeling during first 10 postnatal weeks
    - Contact between femoral head and acetabulum is necessary for normal acetabular development

Gross Pathologic & Surgical Features
- Hourglass-shaped joint capsule
- Femoral head flattened medially
- Thickened tight transverse ligament

Microscopic Features
- Hyperplastic ligamentum teres
- Hypertrophic pulvinar

CLINICAL ISSUES

Presentation
- Most common signs/symptoms
  - Palpable clunk using Ortolani and Barlow maneuvers
- Clinical profile
  - Ortolani maneuver
    - Hip is flexed to 90˚ and gently abducted while thigh is lifted anteriorly
    - "Clunk" is felt as dislocated femoral head reduces
  - Barlow maneuver
    - Hip is flexed to 90˚ and gently adducted while thigh is pushed posteriorly
    - "Clunk" is felt as femoral head dislocates

Demographics
- Age
  - Newborns
- Gender
  - M:F = 1:4
    - Female offspring are particularly susceptible to female hormone relaxin, which may contribute to ↑ ligamentous laxity
  - Left hip is 3x more commonly affected than right hip
    - Possibly related to left occiput anterior position of most nonbreech babies in utero
      - In this position, left hip lies against maternal spine, which may limit abduction
- Epidemiology
  - Dysplasia: 0.8% newborn (0.3% boys, 1.4% girls)
- Risk factors
  - Positive family history, breech presentation, oligohydramnios, torticollis, foot deformity
    - 3% of births are breech; 8% of girls with breech birth have developmental hip dysplasia
    - Due of hip flexed, knee extended position of breech babies in utero

Natural History & Prognosis
- Prognosis
  - Physiological hip joint laxity of newborn without acetabular dysplasia resolves spontaneously
  - Early treatment of DDH: Excellent result with harness or splint
  - Delayed treatment of DDH: Irreversible dysplasia
- Limited range of movement, adductor spasm
- Limb shortening, osteoarthrosis

Treatment
- Conservative
  - Pavlik harness ± closed reduction (if dislocated)
- Surgical for dislocation or subluxation failing to respond to conservative treatment
  - Open reduction + spica cast
  - Adductor tenotomy + release of iliopsoas
  - Varus (derotational) vs. reconstructive osteotomy

DIAGNOSTIC CHECKLIST

Consider
- On ultrasound examination, incorrect orientation can make deep hip appear shallow
  - Not possible to make shallow hip appear deep
- Prognosis is excellent if dysplasia is diagnosed and treated early, even for severe degree of DDH

Image Interpretation Pearls
- Key to diagnosis rests on obtaining correct coronal (longitudinal) view
- Be clear with respect to definitions of capsular laxity, subluxation, and dislocation
  - Useful to have these definitions written on ultrasound report
- If in doubt, repeat ultrasound in 2-4 weeks

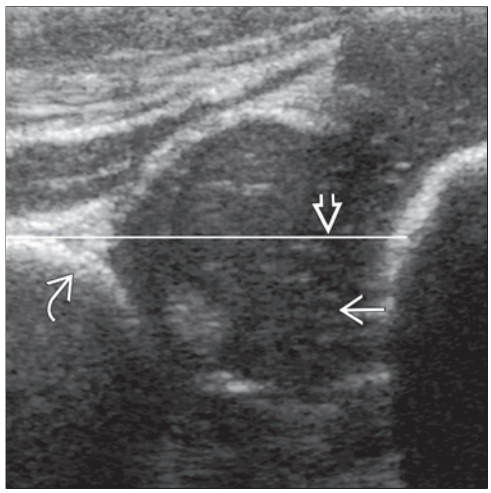
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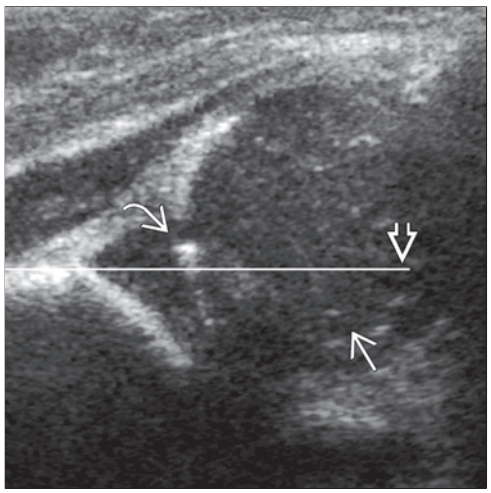
1. Nestorova R et al: Ultrasonography of the hip. Med Ultrason. 14(3):217-24, 2012



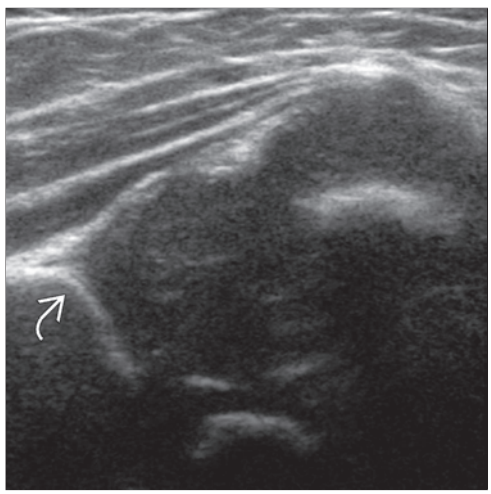


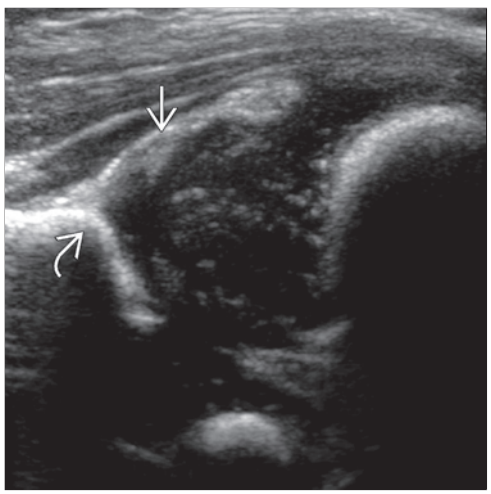
(Left) *Clinical photograph shows the position of a baby during scanning for nonstress views of hip. The baby is in the lateral decubitus position with the hip flexed to only ~ 20°. The transducer is oriented in a nearly coronal position.* ***(Right)*** *Clinical photograph shows the technique for obtaining stress views of the hip. The baby is in a lateral decubitus position. The hip is adducted and flexed, with a steady applied force being directed posteriorly. The transducer remains orientated in a nearly coronal position.*





(Left) *Longitudinal ultrasound shows an immature acetabulum with a roundish acetabular promontory. The majority of the unossified femoral head lies below the iliac line. There is good bony coverage.* ***(Right)*** *Longitudinal ultrasound of the same patient during active hip motion shows that most of the femoral head lies above the iliac line. This indicates capsular laxity and is common in newborns and premature infants. There is some gas in the hip joint. This is a normal finding.*

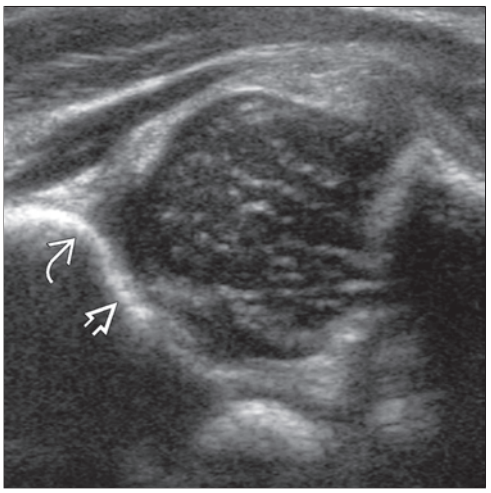


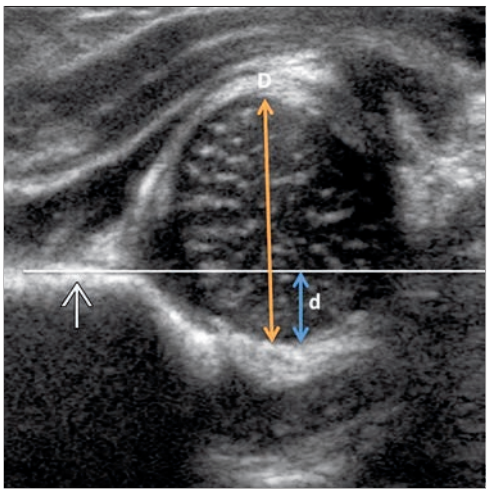


(Left) *Longitudinal coronal ultrasound shows an immature acetabulum with a roundish acetabular promontory. There is good bony coverage of the femoral head.* ***(Right)*** *Longitudinal coronal ultrasound of the hip obtained on follow-up 2 months later (same patient) shows that the previously roundish bony acetabular promontory has now become less rounded. This is an expected finding with normal maturation of the acetabulum. Note the normal acetabular labrum.*

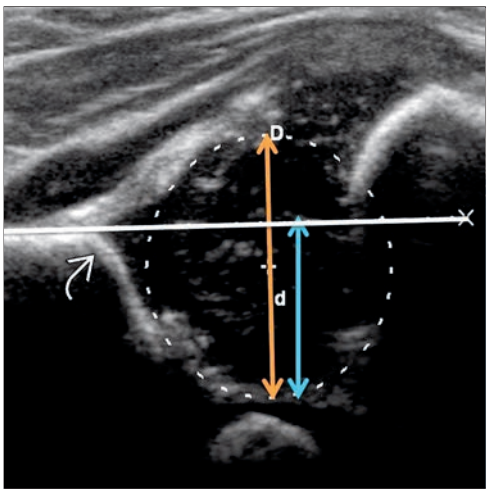
DEVELOPMENTAL HIP DYSPLASIA

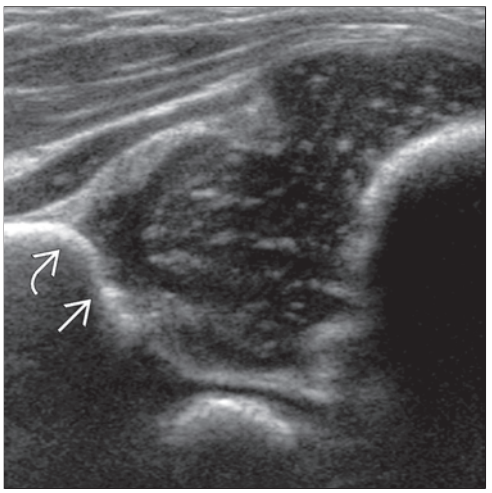
(Left) *Longitudinal coronal ultrasound of a hip shows a roundish acetabular promontory indicative of acetabular immaturity. The acetabular roof is still deep with good bony coverage of the femoral head.* ***(Right)*** *Longitudinal coronal ultrasound scan of the same hip during stress testing shows moderate capsular laxity with < 50% coverage of the femoral head by the bony acetabulum as indicated by the iliac line. Treatment is indicated with follow-up ultrasound in 4 weeks.*



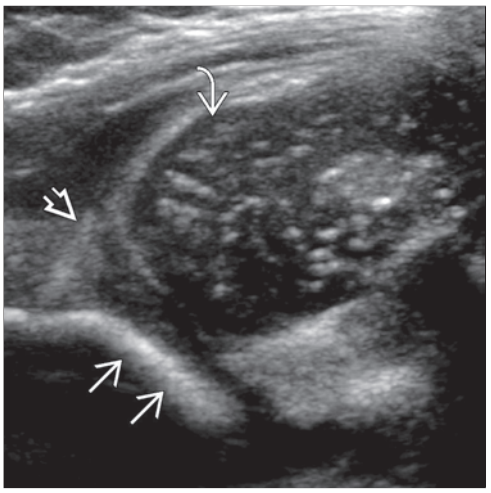


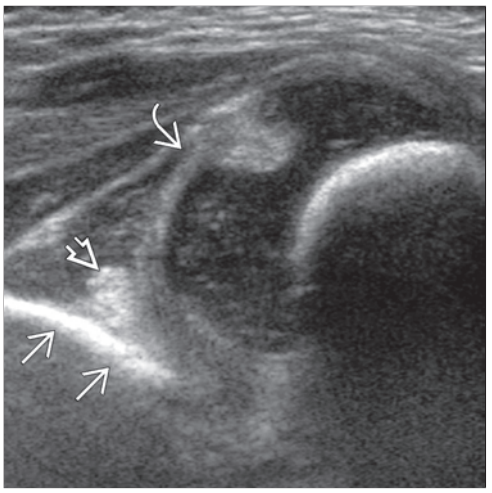
(Left) *Longitudinal coronal ultrasound of the same hip 4 weeks later shows that the femoral head is now not subluxed during stress maneuver, i.e., D/d > 50%. The acetabulum promontory is also sharper. Early diagnosis and proper treatment can lead to dramatic improvement.* ***(Right)*** *Longitudinal ultrasound of the contralateral hip in the same patient shows a slightly roundish acetabular promontory. However, the acetabular bony roof is well formed and deep.*

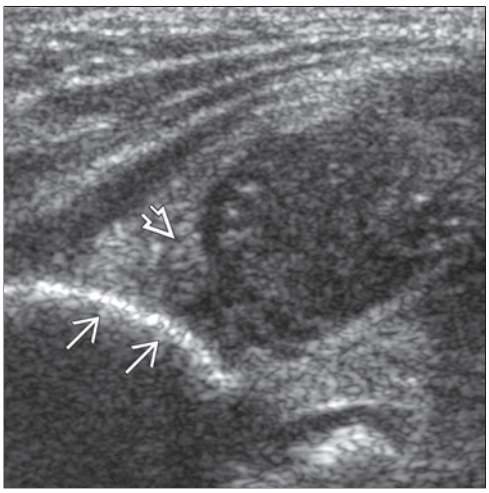


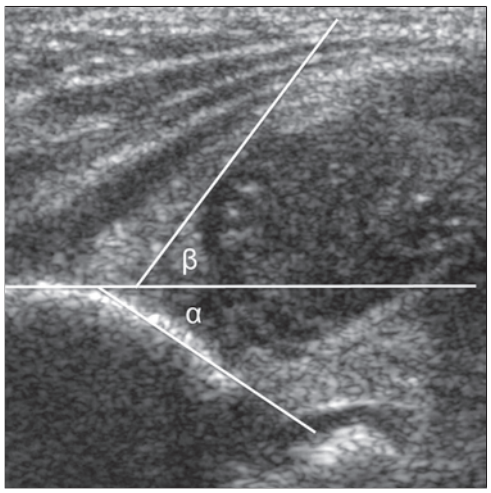


(Left) *Longitudinal coronal ultrasound shows a moderately dysplastic hip with a shallow acetabulum. The α angle is 44˚ (type IIc). Moderate femoral head subluxation is present. The acetabular labrum is everted. The femoral head is relatively small.* ***(Right)*** *Longitudinal ultrasound of a hip shows a severely hypoplastic acetabulum with a dislocated femoral head. The labrum is interposed between the bony acetabulum and the femoral head. Features are compatible with type IV DDH.*

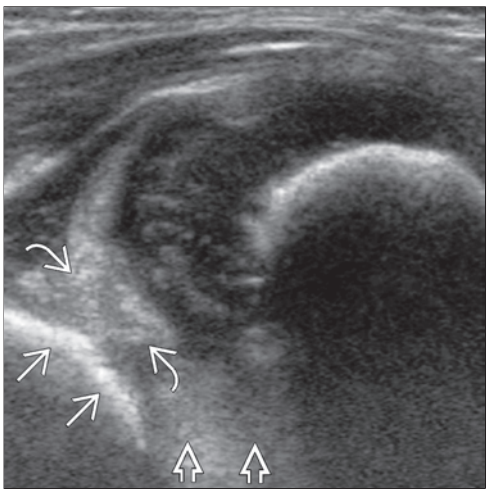


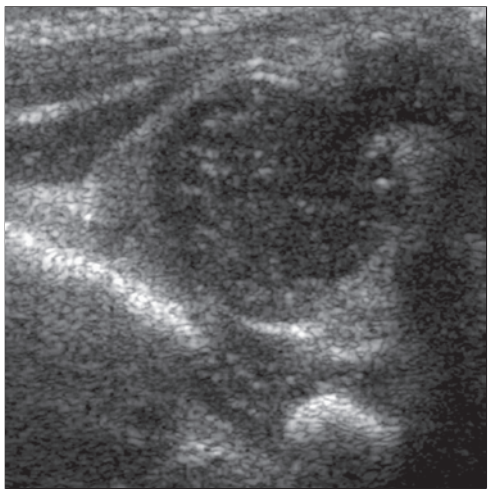




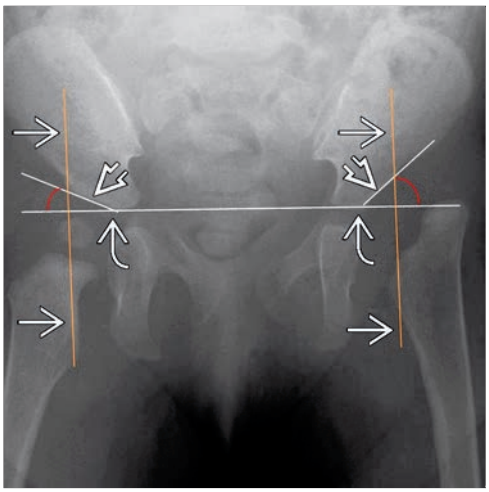


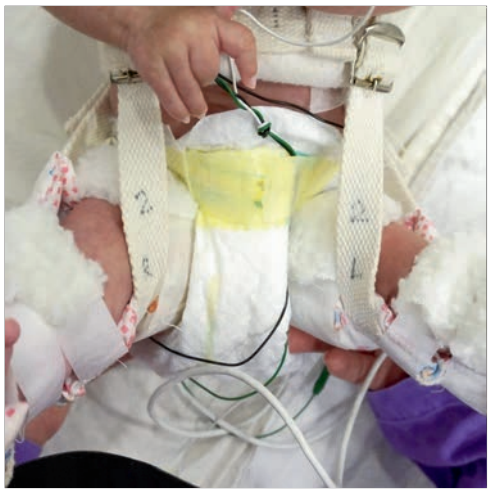
(Left) *Longitudinal ultrasound shows a severely dysplastic hip with a rounded shallow acetabulum. The femoral head is severely subluxed, and the acetabular labrum is located between the acetabulum and the femoral head. These features are compatible with type III DDH.* ***(Right)*** *Longitudinal ultrasound of the hip (same patient) shows severe reduction in α angle measuring 34˚; and increase in β angle measuring 55˚, which is classified as type III DDH.*



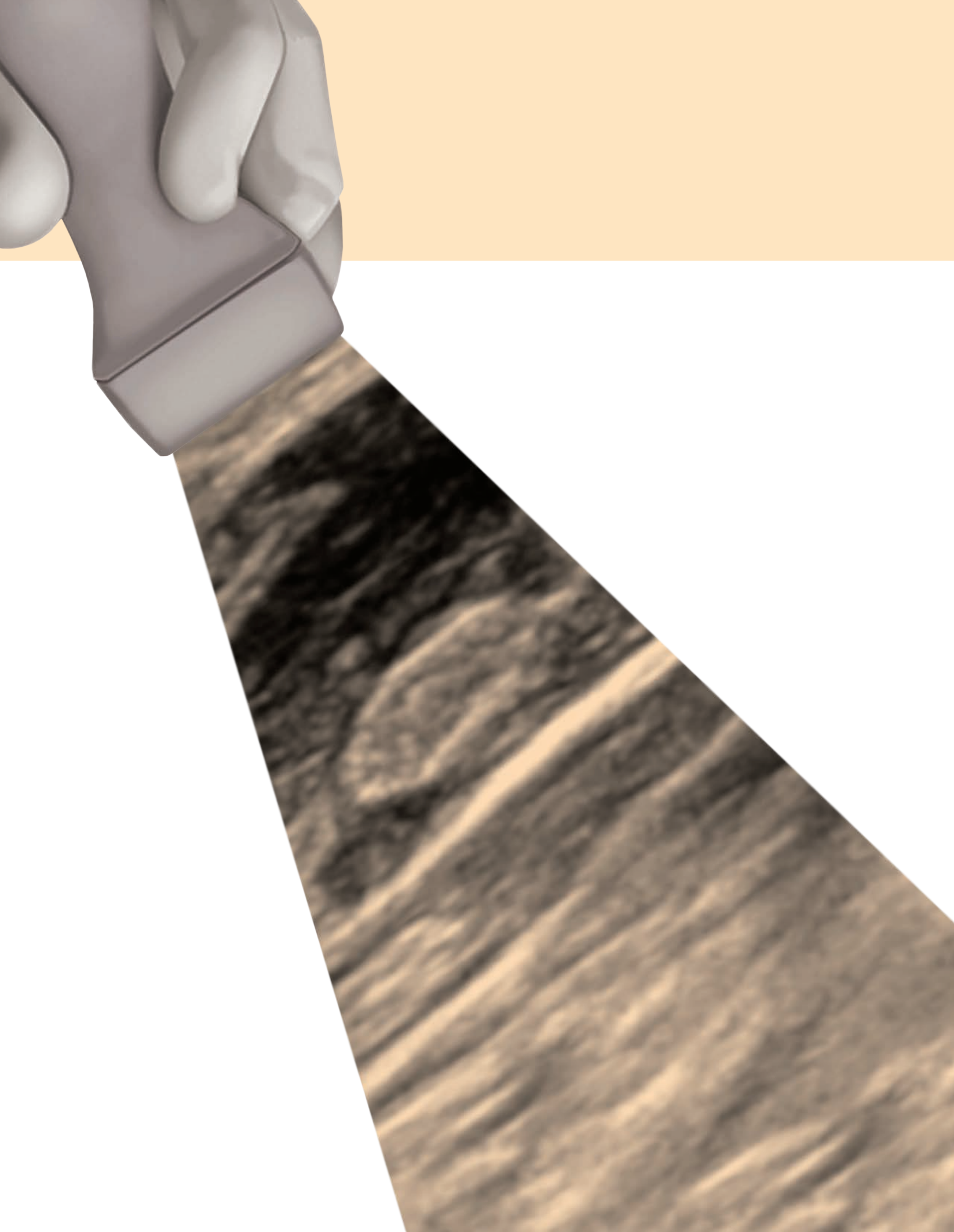


(Left) *Longitudinal ultrasound shows a severely dysplastic hip with lateral and cephalad displacement of the femoral head. The labrum is interposed between the femoral head and acetabulum and is thickened. The pulvinar is also thickened. The hip is classified as type IV DDH.* ***(Right)*** *Longitudinal ultrasound shows a severe dysplastic acetabulum with a dislocated hip. The bony acetabulum is not measurable, and the labrum cannot be well delineated. These features are compatible with type IV DDH.*





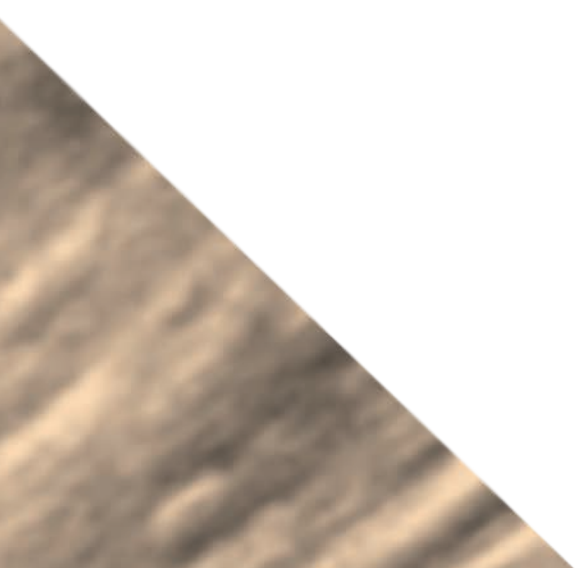
(Left) *Frontal radiograph shows Hilgenreiner, Perkins, and acetabular roof lines as well as acetabular index angles. There is left-sided acetabular dysplasia with dislocation of the femoral head and delayed ossification of the left femoral capital epiphysis.* ***(Right)*** *Clinical photograph shows a baby wearing a Pavlik harness to treat DDH. The harness helps to keep the hips in an abducted flexed position. This position ensures that the femoral heads remain within the acetabular fossae.*



SECTION 5

Neurovascular Abnormalities

Nerve Injury **II**-5-2
Peripheral Nerve Sheath Tumor **II**-5-10
Carpal Tunnel Syndrome **II**-5-22
Cubital Tunnel Syndrome **II**-5-30
Tarsal Tunnel Syndrome **II**-5-34
Vascular Dilatation or Inflammation **II**-5-40



NERVE INJURY

Key Facts

Terminology

- Neurapraxia → impaired nerve function due to conduction block
- Axonotmesis = "axon-cutting" → impaired nerve function due to tear of axon or axons ± sheath
- Neurotmesis = "nerve-cutting" → loss of nerve function due to tear of entire nerve

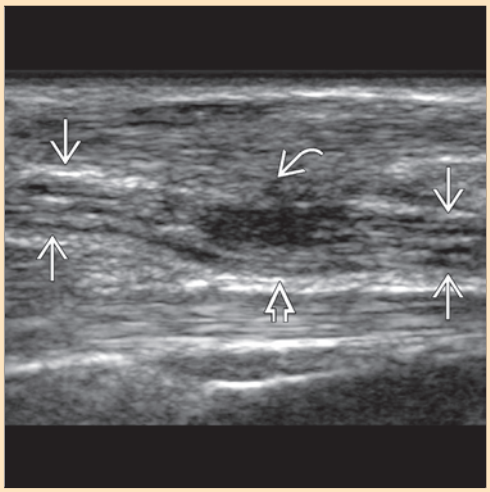
Imaging

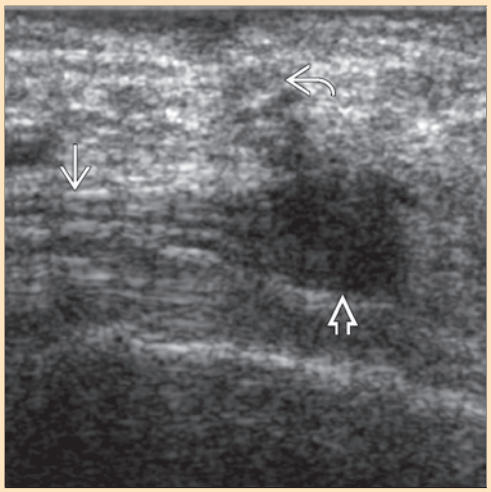
- Disruption of normal fibrillar pattern of nerve + focal nerve swelling
- Digital > median > ulnar > sciatic > radial nerve
- Ultrasound best shows nerve injury
- MR best shows denervated muscle effect
- Scan transversely along course of nerve
  - Observe caliber, integrity of nerve, echogenicity and stiffness of perineural fat
- Then align transducer along long axis of nerve
  - Best plane to appreciate continuity and discontinuity of epineurium and fascicles
  - If partial tear, estimate degree of transection (e.g., 10%, 40%, 90%)
- Neurapraxia: Appearance of nerve and surrounding tissues is usually normal
  - ± focal swelling of nerve
- Axonotmesis: Incomplete tear of nerve
- Neurotmesis: Complete tear of nerve ± retraction

Diagnostic Checklist

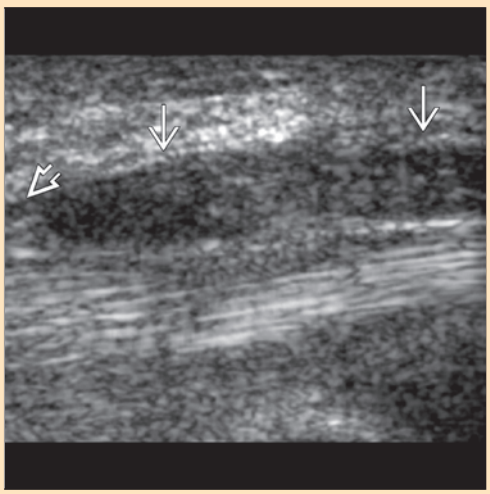
- Ultrasound is very good at localizing site of injury in axonotmesis/neurotmesis and detecting perineural fibrosis/neuroma
- Check for integrity of epineurium followed by integrity of individual fascicles, if visible
- Ultrasound, in general, probably slightly overestimates rather than underestimates nerve injury

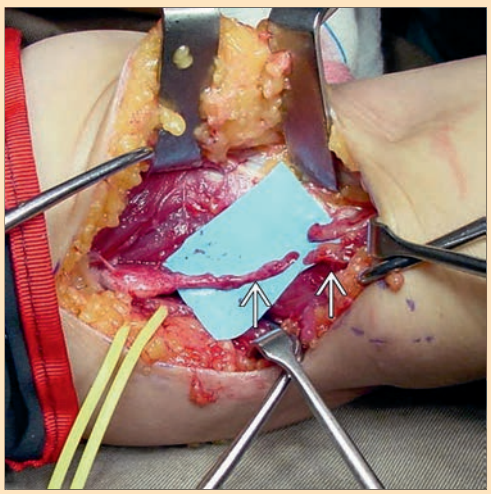
(Left) *Longitudinal ultrasound shows axonotmesis of the median nerve following a laceration with the tear involving the more superficial fascicles. Overall, ~ 50% of the nerve fascicles are estimated to be torn with the deeper fascicles still intact.* ***(Right)*** *Longitudinal ultrasound shows transection of the tibial nerve following a laceration just above the ankle with a medium-sized neuroma of the nerve stump.*





(Left) *Longitudinal ultrasound shows severe swelling of the medial nerve following a forearm chop injury. Nerve continuity is maintained. Surgery revealed an oblique laceration involving 70% of the nerve fascicles. The laceration is not visible on ultrasound but nerve swelling along with continuity provides indirect evidence of a severe partial tear.* ***(Right)*** *Clinical photograph shows the complete transection of median nerve following a forearm laceration. (Courtesy P. C. Ho, MD.)*





NERVE INJURY

TERMINOLOGY

Synonyms
- Neurapraxia: Saturday-night palsy, honeymoon syndrome, crutch syndrome, wheelchair syndrome

Definitions
- Neurapraxia = impaired nerve function due to conduction block
  - Praxis = function (Greek)
- Axonotmesis = "axon-cutting" → impaired nerve function due to tear of axon or axons ± sheath
  - Severity variable depending on number of axons torn
- Neurotmesis = "nerve-cutting" → loss of nerve function due to disruption of entire nerve

IMAGING

General Features
- Best diagnostic clue
  - Disruption of normal fibrillar pattern of nerve + focal nerve swelling
- Location
  - Digital > median > ulnar > sciatic > radial nerve
- Size
  - Ranging from marginally swollen nerve up to ~ 4x normal size
    - Chronic denervation → muscle atrophy
- Morphology
  - Ranges from focal nerve swelling to complete discontinuity with retraction ± neuroma
    - Slightly enlarged muscle in acute denervation → severe fatty atrophy with chronic denervation

MR Findings
- T1WI
  - Acute/subacute denervation → ± mild muscle swelling
  - Chronic denervation → muscle atrophy
- T2WI FS
  - Acute/subacute denervation → hyperintense muscle
    - ± mild increase in muscle size
- T1WI C+
  - Acute/subacute denervation → enhancement of denervated muscle
- Muscle edema and enhancement may be seen 24 hours after denervation
  - Increasing muscle edema parallels increase in muscle enhancement
    - Both probably reflect ↑ capillary engorgement and ↑ blood volume within affected muscle
  - Pattern of muscle involvement can predict likely nerve injury
- Muscle edema and enhancement reverse with reinnervation of muscle

Ultrasonographic Findings
- Detection of injury
  - Neurapraxia
    - Appearance of nerve and surrounding tissues is usually normal
    - ± focal swelling of nerve
  - Axonotmesis and neurotmesis
    - Disruption of nerve continuity
    - Disruption of fibrillar pattern
    - ± surrounding hemorrhage or edema
    - Evaluation in acute stage may be limited due to artifact caused by overlying wound
- Localization of injury
  - Nerves divide at inconstant levels
  - Ultrasound can depict bifurcation level and confirm if main or distal branch is affected
- Type of injury
  - Axonotmesis: Incomplete tear of nerve
  - Neurotmesis: Complete tear of nerve ± retraction
    - Retraction of nerves < tendon retraction
    - Up to few cm
    - Nerve injury overlying mobile joint leads to greater retraction
- Presence of perineural fibrosis
  - Irregular hypoechoic tissue replacing echogenic perineural fat
  - Focal swelling of nerve
  - ± tethering of nerve
  - ± reduced motility of nerve on moving part
- Continuity of nerve postoperatively
  - Continuity of epineurial sheath
    - ± continuity of nerve fascicles
- Presence of neuroma
  - Quite common finding
  - Hypoechoic rounded or ovoid mass at site of disrupted nerve
  - Connected to proximal end of severed nerve
  - Largely avascular
  - May be small and intraneural
    - Small neuromas may be difficult to distinguish from nodular fibrosis
  - Vast majority associated with complete nerve transection though minority can occur with partial nerve transection
- Muscle denervation
  - Mild swelling and increased echogenicity of affected muscle seen after 2 weeks
    - Due to capillary dilatation and muscle edema
  - Later → decreased muscle bulk and increased echogenic fat within and between muscle bundles
    - Due to muscle atrophy and fatty replacement

Imaging Recommendations
- Best imaging tool
  - Ultrasound best shows nerve injury
    - High resolution
    - Easy orientation along long and short axes of nerve
  - MR best shows denervated muscle effect
- Protocol advice
  - Scan transversely along course of nerve
    - Easiest plane to trace course of nerve
  - Observe caliber, integrity of nerve, echogenicity and stiffness of perineural fat
  - Align transducer along long axis of nerve
    - Best plane to appreciate continuity and discontinuity of epineurium and fascicles
    - If partial tear, estimate degree of transection (e.g., 10%, 40%, 90%)
    - Measure retraction gap, if present
  - Observe nerve movement when passively moving adjacent joints

NERVE INJURY

DIFFERENTIAL DIAGNOSIS

Tendon Injury
- Sometimes torn in conjunction with nerve
- Discontinuity of tendon fibers

Nerve Sheath Tumor
- May mimic traumatic neuroma
- Entering and exiting nerve
- Traumatic neuromas are less vascular

Nerve Entrapment
- Typical locations
- Nerve swelling proximal to level of entrapment
- → demyelination (neurapraxia) of entrapped nerve with secondary changes in affected muscle

PATHOLOGY

General Features
- Etiology
  - Blunt or penetrating trauma
    - Includes iatrogenic causes: Fracture repair and fixation, arthroscopy, carpal tunnel release, surgical exploration
- Relevant anatomy
  - Axon ± covered by myelin (myelinated or non-myelinated nerve fiber)
  - Endoneurium = loose connective tissue between nerve fibers
  - Perineurial sheath groups nerve fibers into fascicles
  - Epineurium encircles and runs between fascicles; outer layers of epineurium are condensed into sheath
- Fascicles within large peripheral nerve continually divide and reunite (fascicular plexus)
  - Particularly in lumbar and brachial plexuses

Staging, Grading, & Classification
- Sunderland grading system
  - Grade 1: Neurapraxia
    - Neural tubes intact
      - No axonal regeneration required
  - Grade 2-4: Axonotmesis
    - Grade 2: Axon is disrupted but endo-, peri-, and epineurium intact
      - Regenerating axons always reach original motor and sensory targets
    - Grade 3: Axons and endoneurium are disrupted but peri- and epineurium intact
      - Regenerating axons may not reach original motor and sensory targets
    - Grade 4: Axons, endo- and perineurium are disrupted but epineurium is intact
      - Regenerating axons usually do not reach original motor and sensory targets
  - Grade 5: Neurotmesis
    - Complete transection of all neural tubes
      - Regenerating axons invariably do not reach original motor and sensory targets
    - Classification system is difficult to apply clinically as mixed injury is common

Gross Pathologic & Surgical Features
- Axonal injury → wallerian degeneration → regeneration

Microscopic Features
- Axonal apoptosis followed by phagocytosis
- Schwann cell proliferation
- Sprouting axonal filopodia → growth cone, guided by neurotrophic and neurotropic mediators

CLINICAL ISSUES

Presentation
- Most common signs/symptoms
  - Weakness ± numbness ± pain
- Other signs/symptoms
  - Type of transection, nerve function fails sequentially
  - Motor → proprioception → touch → temperature → pain → autonomic
    - Recovery in reverse order

Demographics
- Age
  - More common in young adults
- Gender
  - M:F = 2.2:1
- Epidemiology
  - 2-3% patients admitted to level I trauma center
  - More common in dominant limb

Natural History & Prognosis
- Neurapraxia has an excellent prognosis
- Axonotmesis and neurotmesis have a variable prognosis depending on degree of injury
- Axons regenerate at ~ 1 mm/day (slower in older patients)

Treatment
- Neurapraxia: Supportive treatment
- Axonotmesis or neurotmesis
  - Immediate or delayed repair
    - Immediate repair if clean wound, no crush injury, good vascular supply and soft tissue coverage
  - End-to-end closure
  - Nerve graft ± vascularization
  - Nerve transfer

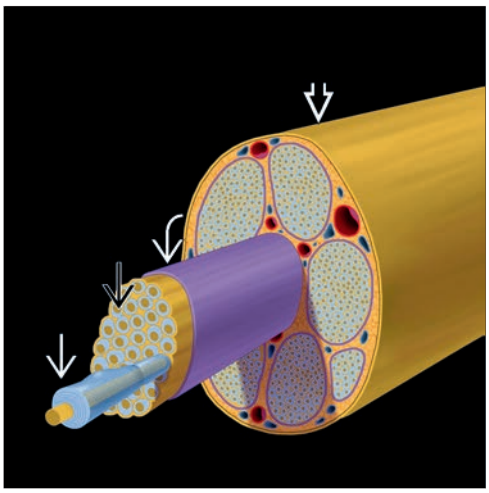
DIAGNOSTIC CHECKLIST

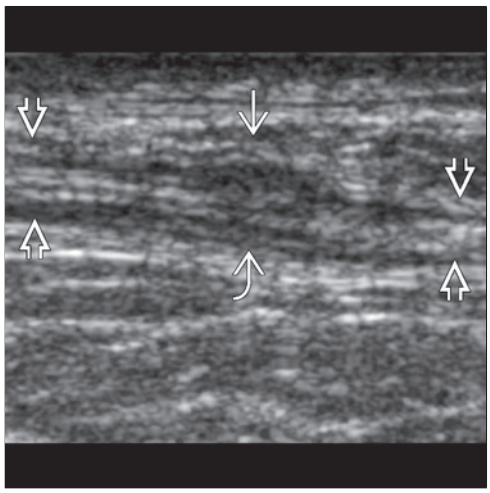
Consider
- Ultrasound is very good at localizing site of injury in axonotmesis/neurotmesis and detecting perineural fibrosis/neuroma
  - In general, ultrasound probably slightly over- rather than underestimates nerve injury

Image Interpretation Pearls
- Determine whether nerve is simply bruised or actually torn; if torn, then by how much is it torn?

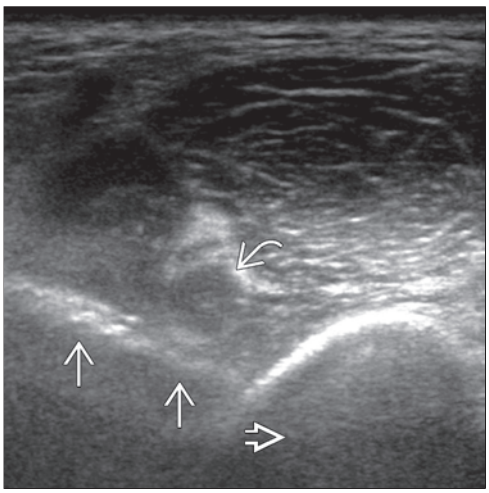
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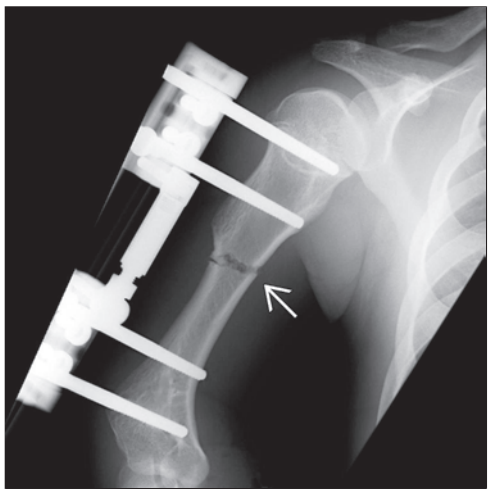
1. Hobson-Webb LD et al: Ultrasonography in the diagnosis of peripheral nerve disease. Expert Opin Med Diagn. 6(5):457-71, 2012



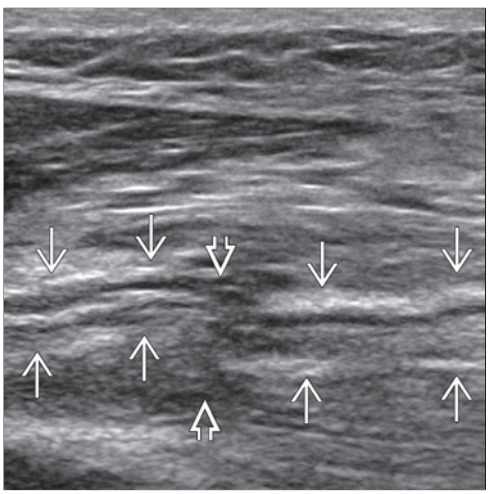


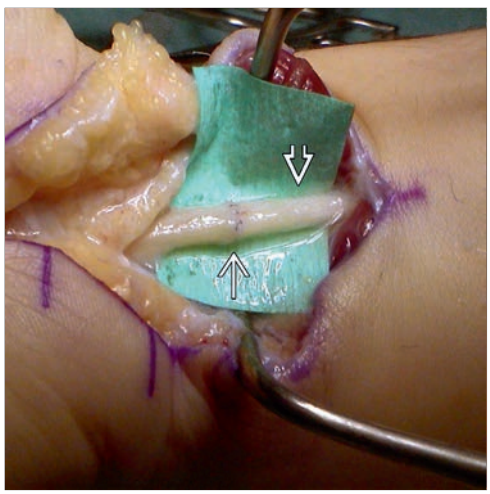
(Left) *Graphic of normal nerve structure shows myelinated axons* ➡ *embedded in endoneurium* ➡ *(seen as yellow). The fascicles are surrounded by perineurium* ➡. *The nerve is surrounded by epineurium* ➡. ***(Right)*** *Longitudinal ultrasound shows focal disruption and swelling of the superficial part of the epineurium* ➡ *and fascicles of the median nerve* ➡ *following a dog bite, indicating axonotmesis. ~ 30% of the cross-sectional area of the nerve is torn. The epineurium on the deep part of the nerve is intact* ➡.





(Left) *Transverse ultrasound shows moderate swelling of the radial nerve* ➡ *in an achondroplastic patient who developed wrist drop following internal fixation* ➡ *for lengthening of the humerus* ➡. *No nerve discontinuity was present (neurapraxia). Symptoms slowly resolved over several months with conservative treatment only.* ***(Right)*** *Radiograph of the same patient shows the humeral lengthening fixation device and the site of humeral transection* ➡.

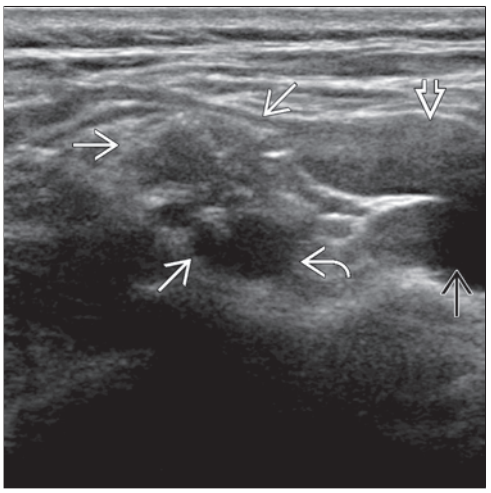


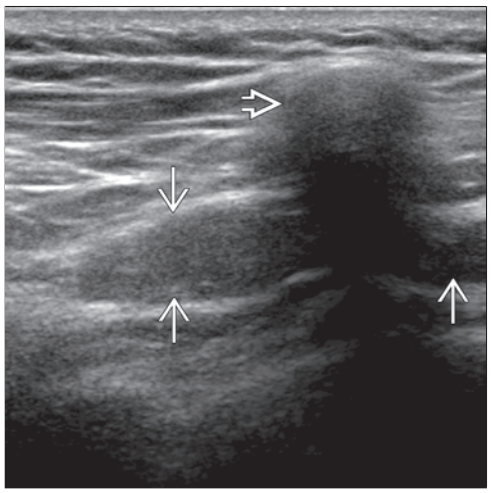


(Left) *Longitudinal ultrasound of the posterior arm region following a chop injury shows complete laceration* ➡ *(neurotmesis) and mild displacement of a swollen radial nerve* ➡ *following a chop injury.* ***(Right)*** *Clinical photograph shows repaired* ➡ *complete transection (neurotmesis) of the median nerve* ➡. *Most traumatic nerve injuries are readily apparent clinically and usually do not require preoperative imaging. (Courtesy P. C. Ho, MD.)*

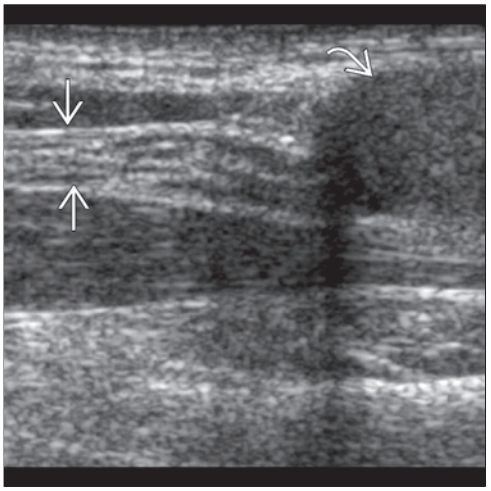
NERVE INJURY

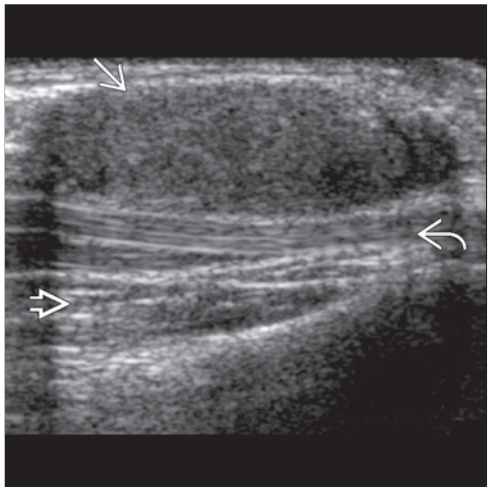
(Left) *Transverse ultrasound shows severe diffuse postoperative fibrosis involving nearly all of the infraclavicular brachial plexus following resection of a schwannoma 1 year earlier. Nodular fibrosis particularly involves the medial cord. The subclavian vein and artery are normal.* ***(Right)*** *Longitudinal ultrasound in the same patient shows severe hypoechoic fibrosis involving the infraclavicular brachial plexus. The clavicle is normal.*



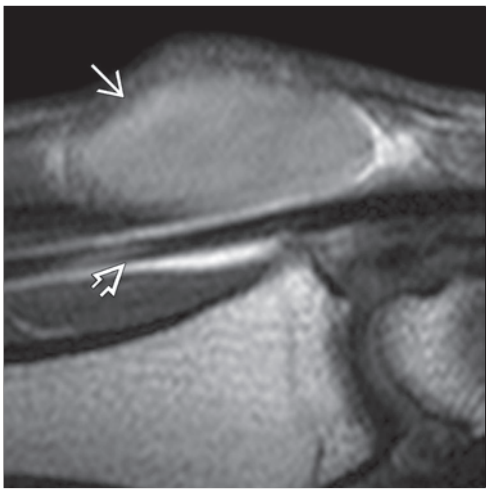


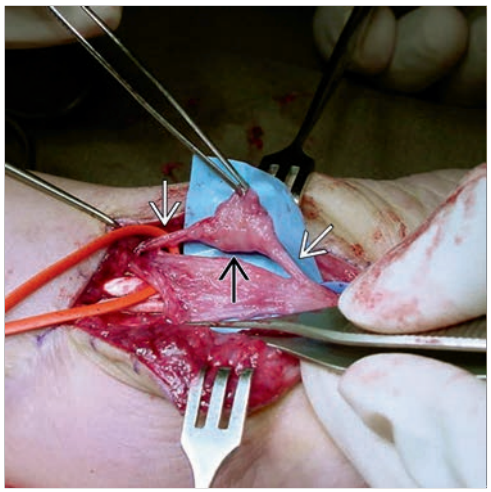
(Left) *Longitudinal ultrasound shows neuroma at the distal end of mildly swollen transected median nerve.* ***(Right)*** *Longitudinal ultrasound immediately distal to previous image shows an oval-shaped hypoechoic neuroma of the proximal stump of transected median nerve. There is moderate posterior acoustic enhancement. The underlying flexor tendon is normal.*

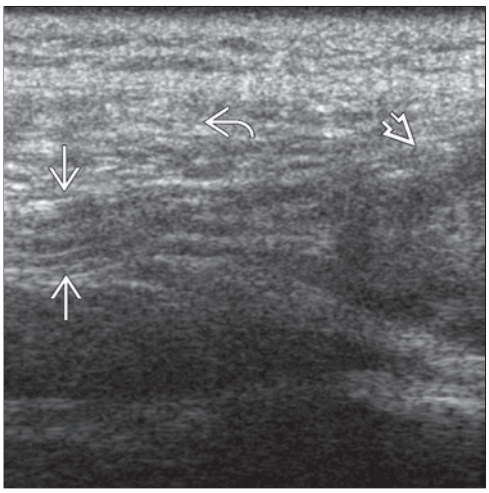




(Left) *Longitudinal T2WI MR of the same patient shows an ovoid post-traumatic neuroma of the medial nerve at the wrist level. The flexor tendon deep to the neuroma is normal.* ***(Right)*** *Clinical photograph shows a post-traumatic neuroma of the median nerve. The neuroma connects the 2 torn nerve endings. The majority of traumatic neuromas occur following complete nerve transection, though a minority can arise from incomplete nerve transection. (Courtesy P. C. Ho, MD.)*

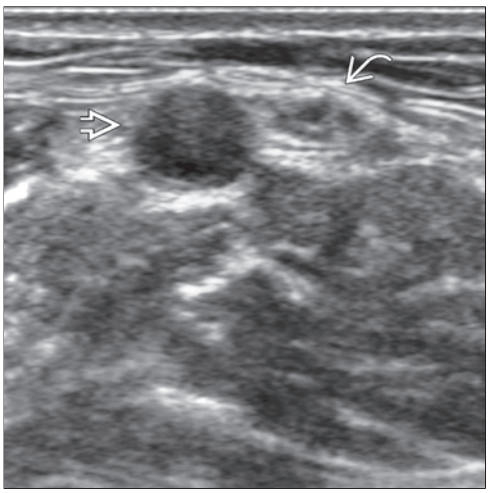


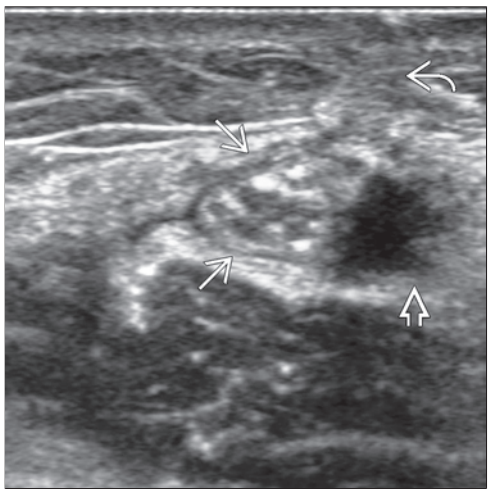




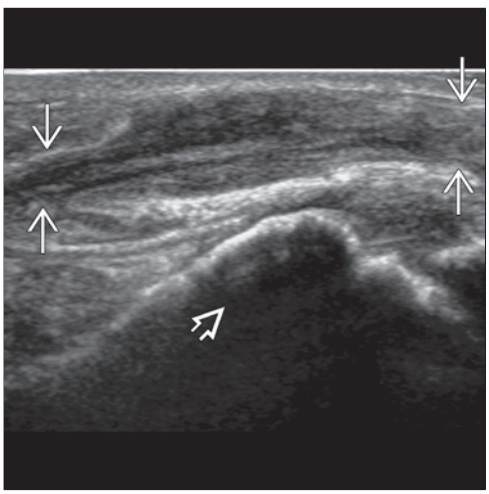


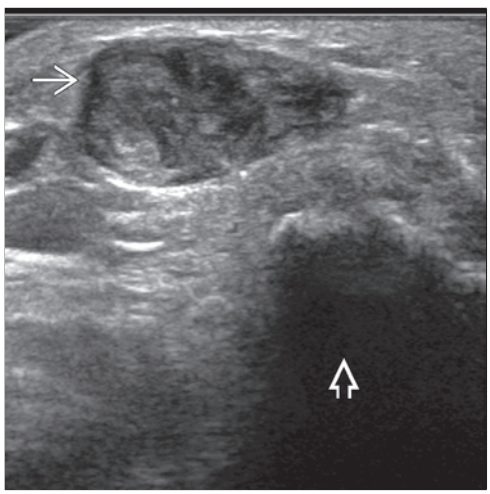
(Left) *Longitudinal ultrasound of the stump in a patient with above-knee amputation for osteosarcoma shows a bulbous swelling at the distal end of the sciatic nerve. There is severe muscle atrophy present. **(Right)** Coronal T1WI MR in the same patient as previous image shows the neuroma at the distal end of the transected sciatic nerve.*





(Left) *Transverse ultrasound of distal arm shows normal median nerve alongside brachial artery. **(Right)** Transverse ultrasound of opposite arm in the same patient who developed symptoms of median nerve injury following brachial artery cannulation for endovascular procedure. The median nerve is swollen to about three times normal size. No transection was present on longitudinal scanning consistent with severe neurapraxia. The surrounding soft tissues are swollen, the brachial artery is irregular and the surgical scar is visible.*

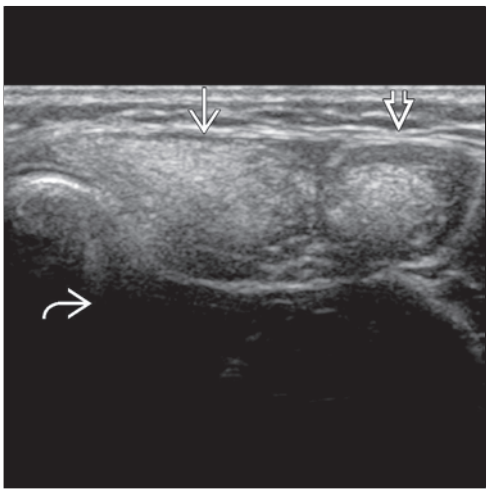


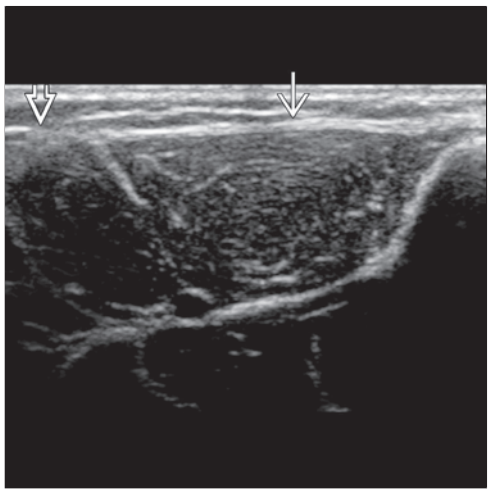


(Left) *Longitudinal ultrasound shows a patient with open fracture of the humeral medial epicondyle associated with ulnar nerve contusion and epineural abrasion in whom ulnar nerve transposition was performed. This shows a severely swollen, though continuous ulnar nerve, transposed anterior to the medial epicondyle. **(Right)** Transverse ultrasound in the same patient shows the very swollen ulnar nerve, consistent with severe neurapraxia, anterior to the medial epicondyle.*

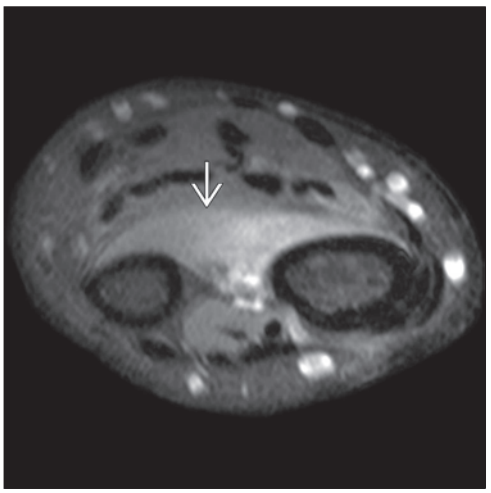
NERVE INJURY

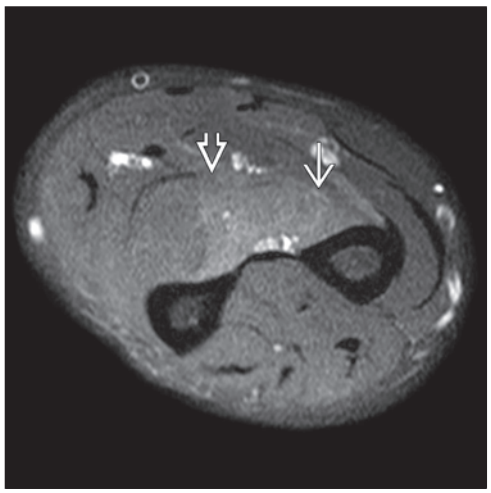
(Left) *Transverse ultrasound of the leg in a young patient with previous deep peroneal nerve injury shows severe fatty atrophy of the anterior compartment muscles (tibialis anterior and extensor digitorum longus). The tibia is normal.* ***(Right)*** *Transverse ultrasound of the contra lateral limb in the same patient shows the normal tibialis anterior and extensor digitorum longus muscles for comparison.*



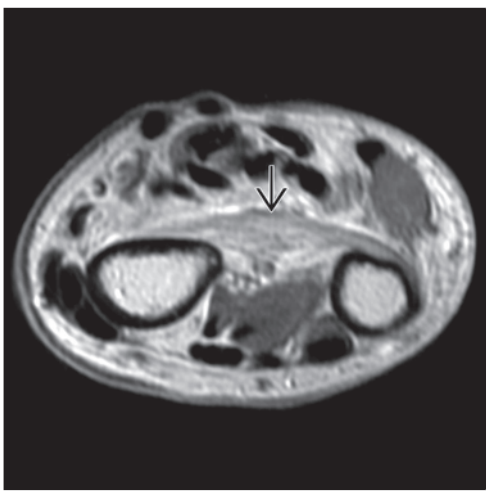


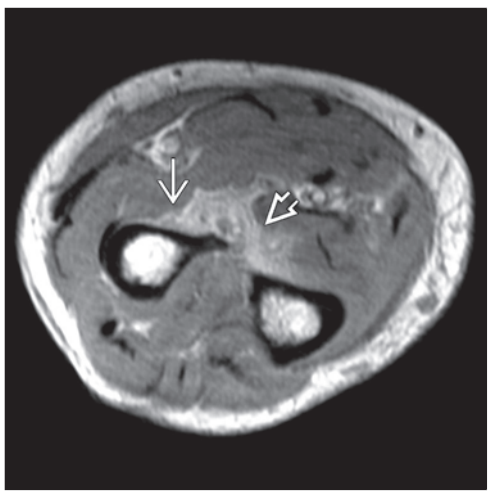
(Left) *Axial T2WI FS MR in a patient with forearm pain and weakness of thumb pincer movement shows moderate edema of the pronator quadratus muscle.* ***(Right)*** *Axial T2WI FS MR in the same patient shows mild edema of the flexor pollicis longus and flexor digitorum profundus (index and middle) consistent with subacute anterior interosseous syndrome (AIS). Mild muscle edema is more easily appreciated on MR than ultrasound.*

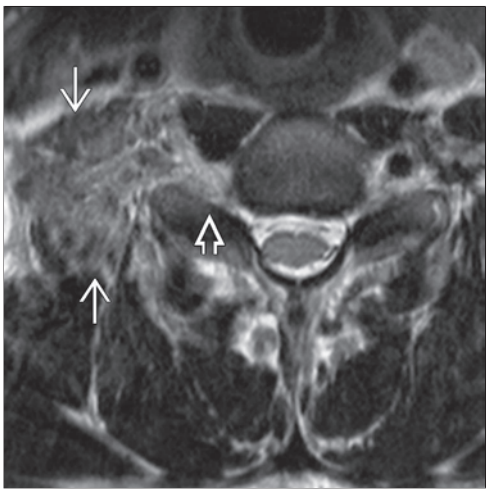




(Left) *Axial T1WI MR shows severe fatty atrophy of the pronatus quadratus muscle due to chronic AIS.* ***(Right)*** *Axial T1WI MR in the same patient shows severe atrophy of the flexor pollicis longus and flexor digitorum profundus (index and middle) muscles. Most cases of AIS are due to a neuritis (brachial neuritis), with median nerve compression and trauma being less common causes. MR allows better perception of muscle atrophy than ultrasound.*

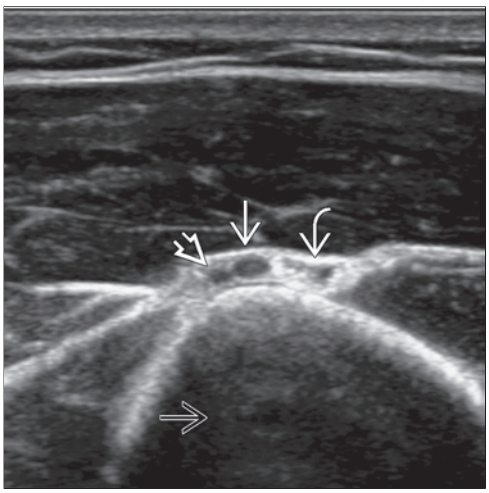


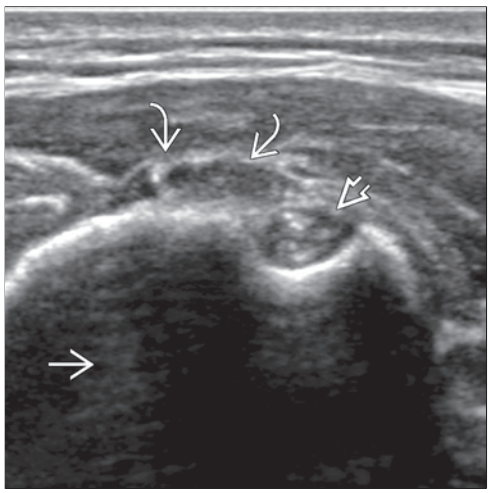




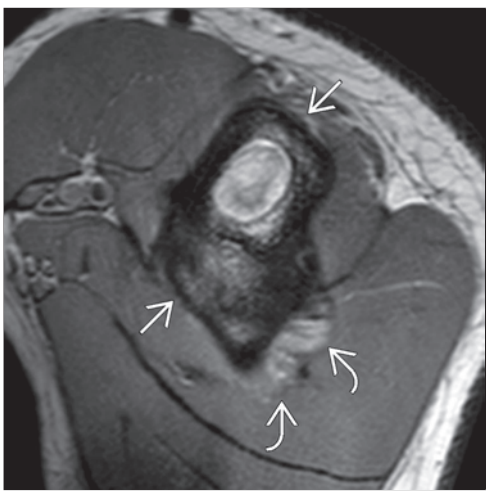


(Left) *Axial T2WI MR shows hematoma just outside and within the right C6/7 exit foramen in a patient with traction injury to the brachial plexus. This suggests an avulsive injury of the C7 root.* ***(Right)*** *Sagittal T2WI MR in the same patient shows a small hematoma at the edge of the spinal cord at the site of origin of the right C7 suggestive of an avulsive nerve root injury. MR, rather than ultrasound, is recommended in traction injury of the brachial plexus.*





(Left) *Transverse ultrasound shows the normal radial nerve at the posterior aspect of humeral shaft . There is an accompanying profunda brachii artery and vein .* ***(Right)*** *Transverse ultrasound in a patient with a healed malaligned humerus shaft fracture and radial nerve palsy shows a thickened radial nerve that has become partially entrapped in fracture callus at the posterior aspect of the fracture site.*





(Left) *Axial PDWI MR in the same patient shows the thickened radial nerve at the posterior aspect of the malaligned humeral shaft .* ***(Right)*** *Axial PDWI MR in the same patient shows the radial nerve partially entrapped in healed fracture callus at the posterior aspect of humeral shaft. Because the radial nerve palsy was gradually improving with conservative treatment, no surgical intervention was undertaken.*

PERIPHERAL NERVE SHEATH TUMOR

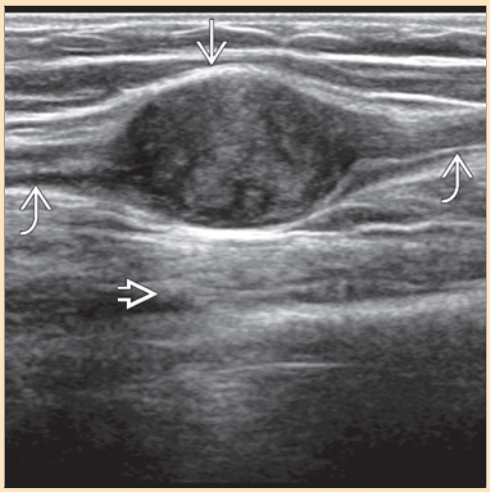
Key Facts

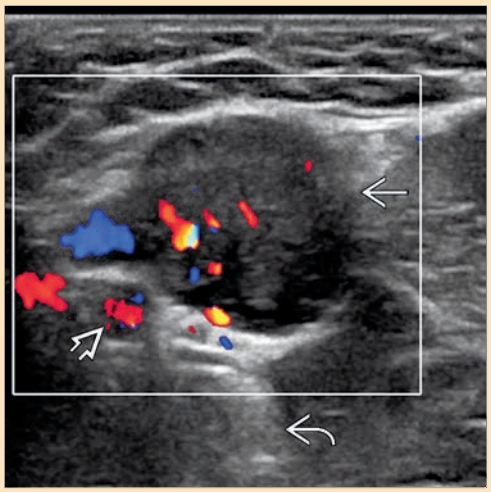
Terminology
- Tumor arising from nerve; histologically classified as either schwannoma or neurofibroma
- 3 types of neurofibroma: Localized, diffuse, and plexiform

Imaging
- Any peripheral nerve can be affected
- Intermuscular > subcutaneous > intramuscular
- Well-defined, largely homogeneous, hypoechoic mass
- Typically fusiform or oblong-shaped and oriented along long axis of nerve
- Nerve sheath tumors align centrally or eccentrically along course of nerve; arise from neurovascular bundle
- Nerve entering or exiting from tumor is seen in majority (90%) with high-resolution ultrasound
- Posterior enhancement is common (70%)
- Nerve sheath tumors, especially schwannoma, often contain cystic areas representing myxoid degeneration, hemorrhage, or necrosis
- Vascular pattern varied; usually moderate degree of intrinsic vascularity is present
- Ultrasound appearances of schwannoma and neurofibroma overlap considerably
- Ultrasound appearances of benign and malignant nerve sheath tumors overlap considerably
- Accurate diagnosis of nerve sheath tumor is usually feasible based on ultrasound findings alone
  - MR is better at assessing the extent of large and deep-seated tumors

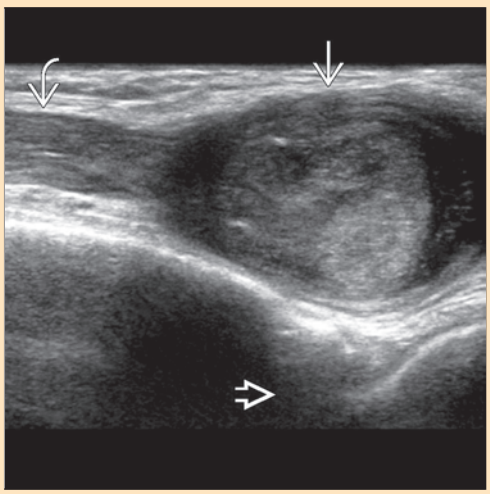
Diagnostic Checklist
- Consider nerve sheath tumor even if parent nerve is not seen, provided other ultrasound features are compatible

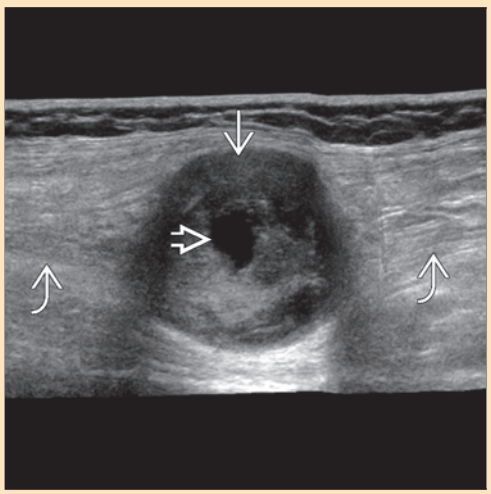
(Left) *Longitudinal ultrasound shows a fusiform homogeneous, hypoechoic mass in continuity with the ulnar nerve with posterior acoustic enhancement. Note the entering & exiting components of the ulnar nerve.* ***(Right)*** *Transverse color Doppler ultrasound of the same lesion shows a moderate degree of intralesional hypervascularity. The lesion is arising from the neurovascular bundle and is located alongside the ulnar artery. Note the moderate posterior acoustic enhancement.*





(Left) *Longitudinal ultrasound shows a heterogeneous nerve sheath tumor from the deep peroneal nerve. The peroneal nerve is thickened proximally due to tumor extension along the nerve. Note the ankle joint.* ***(Right)*** *Extended field-of-view ultrasound shows a histologically proven schwannoma with a central myxoid component and prominent posterior acoustic enhancement arising from the sciatic nerve. Note the strong posterior acoustic enhancement.*





PERIPHERAL NERVE SHEATH TUMOR

TERMINOLOGY

Definitions
- Tumor arising from peripheral nerve and histologically classified as schwannoma and neurofibroma

Associated Syndromes
- Neurofibromatosis type 1 (NF1), von Recklinghausen disease

IMAGING

General Features
- Best diagnostic clue
  - Well-defined largely hypoechoic mass arising from nerve
- Location
  - Any peripheral nerve
    - Intermuscular > subcutaneous > intramuscular
    - Ulnar nerves and peroneal nerves are most frequently affected by schwannoma
    - Subcutaneous nerves are most commonly affected by neurofibroma
  - Head & neck > upper limbs > lower limbs >> trunk
- Size
  - Usually < 5 cm
    - Larger tumors from large nerves (up to 20 cm)
  - Nerve tumors usually grow slowly until critical mass reached and then stop growing
- Morphology
  - Soft tissue mass along neurovascular bundle

MR Findings
- T1WI
  - Soft tissue mass isointense to muscle
  - Split-fat sign (intermuscular fat splits to encompass tumor)
- T2WI
  - Well-defined fusiform mass hyperintense to muscle; "target" sign hypointense center due to collagen and condensed Schwann cells
  - Neural tail sign
- T1WI C+
  - Variable enhancement: May see mainly peripheral enhancement or "reverse target" sign (enhancement of central fibrous component but no enhancement of peripheral myxoid component)
- MR appearances of schwannoma and neurofibroma overlap considerably

Ultrasonographic Findings
- Well-defined, largely homogeneous, hypoechoic mass; occasionally heterogeneous
  - Heterogeneity due to myxoid component, hemorrhage, fibrosis, or calcification
    - "Target" sign: Central hyperechogenicity representing fibrocollagenous component surrounded by peripheral hypoechogenicity representing myxoid component; more commonly seen in neurofibroma
  - Intratumoral hemorrhage may lead to sudden ↑ in tumor size
- Arise from nerve
  - Typically fusiform or oblong in shape and oriented along long axis of nerve
    - Nerve sheath tumors align centrally or eccentrically along course of nerve
  - Nerve entering or exiting from tumor is seen in majority (90%) with high-resolution ultrasound
    - Nerve often shows slight enlargement just proximal and distal to tumor
    - Entering/exiting nerve may not be seen when nerve sheath tumor arises from small peripheral nerves
    - Compressed fascial planes may simulate a nerve on longitudinal imaging; always confirm on transverse plane
- Nerve sheath tumors often contain cystic areas
  - Degenerative ancient schwannomas are predominantly cystic
  - Cystic areas can be due to myxoid accumulation, previous hemorrhage, or necrosis
  - Cystic areas are more common to schwannoma though also commonly seen in neurofibroma
- Occasionally tumor has echogenic rim due to fibrous capsule, fibrous pseudocapsule, or compression of surrounding fat
- Vascular pattern varied
  - Usually moderately vascular with central irregular vascular pattern
    - Some display predominantly peripheral vascularity
    - Some do not have any demonstrable vascularity on color Doppler imaging
  - Vascularity may blanch with transducer pressure
- Diffuse thickening of skin and subcutis with retinacular pattern of enhancement in diffuse neurofibroma
- Diffuse nodular enlargement of nerves with "bag of worms" appearance in plexiform neurofibroma
- Ultrasound diagnosis of nerve sheath tumor is based on consortium of features rather than single feature
  - Ultrasound features usually typical enough to make diagnosis without need for biopsy
    - Biopsy may be very painful
- Ultrasound appearances of schwannoma and neurofibroma overlap considerably
  - Do not focus on making this histological distinction on imaging
  - Report on centric/eccentric location of tumor to parent nerve, if visible, rather than likely cell type
- Ultrasound appearances of benign and malignant nerve sheath tumors overlap considerably
  - No single feature can reliably differentiate between benign and malignant peripheral nerve sheath tumor
  - Clinical features of large size (> 5 cm), rapid growth, and change in neurology are relatively more reliable indicators
  - Irregular margins, inhomogeneity, internal necrosis, and peritumoral inflammation are also more common in malignant peripheral nerve sheath tumors
- PET imaging is more accurate in predicting malignancy in plexiform neurofibromas

Imaging Recommendations
- Best imaging tool
  - Diagnosis of nerve sheath tumor is generally feasible based on ultrasound findings alone
  - MR better at assessing large or deep-seated tumors

PERIPHERAL NERVE SHEATH TUMOR

DIFFERENTIAL DIAGNOSIS

Lymph Node
- Malignant or lymphomatous node with loss of distinction cortex and hilum may simulate nerve sheath tumor
  - Do not have entering or exiting nerve
  - Occur at different locations than nerve sheath tumors

Ganglion
- May simulate ancient schwannoma
- Do not have entering or exiting nerve
- Communication with joint or tendon seen

Vascular leiomyoma
- Do not have entering or exiting nerve
- May be painful
- Typically has eccentric vascular confluence

PATHOLOGY

General Features
- Genetics
  - NF1, von Recklinghausen disease
    - Autosomal dominant
    - Genetic mutation on *NF1* gene chromosome 17
    - Affects 1 in 3,000 people
    - 50% of cases arise from new mutation

Staging, Grading, & Classification
- Schwannoma
  - Usually solitary and sporadic; multiplicity associated with NF1
  - Malignant change extremely rare
- Neurofibroma
  - 3 types
    - Localized: Most are solitary and are not associated with NF1
    - Diffuse: Most are solitary; 10% are associated with NF1
      - Infiltrative retinacular pattern in subcutaneous tissue or plaque-like thickening of skin and subdermal tissues
    - Plexiform: Pathognomonic of NF1
      - Multinodular confluent neural mass with mass effect on bones, lungs, or gastrointestinal tract; "bag of worms"
  - Malignant change occurs in 15% of NF1 patients
    - Common with plexiform neurofibromas (50% risk of malignant transformation), less common with diffuse neurofibroma and rare in localized neurofibroma

Gross Pathologic & Surgical Features
- Schwannoma
  - Mesenchymal tumors with cellular differentiation to Schwann cells; myelin-producing neuroglial cells covering peripheral axons
  - True capsule composed of epineurium
  - Tumors lie eccentric to nerve with nerve fascicles displaced to periphery of tumor mass
  - Tend to be more prone to myxoid degeneration, hemorrhage, and calcification
- Neurofibroma
  - Mesenchymal tumors with cellular differentiation into various neural and perineural cell elements
  - Tumors may not be covered by epineurium
  - Tumors cannot be separated from parent nerve

Microscopic Features
- Schwannoma
  - Intermixed Antoni A areas: Cellular, arranged in short bundles or interlacing fascicles; Antoni B areas: Less cellular and organized, more myxoid component
  - Immunohistochemistry: S100 protein strongly positive
- Neurofibroma
  - Does not contain Antoni A or B areas
  - Composed of interlacing bundles of multiple cells composed of axonal processes, Schwann cells, fibroblasts, perineural cells, and mast cells; often contains abundant amount of collagen
  - Involvement of the nerve fibers
  - Immunohistochemistry: S100 protein positive in localized and diffuse neurofibroma but not as extensive as in schwannoma

CLINICAL ISSUES

Presentation
- Most common signs/symptoms
  - Slowly growing painless mass with positive Tinel sign
- Clinical profile
  - NF1: Neurofibromatosis
    - Café au lait macules, axillary or inguinal freckling, optic nerve glioma, iris Lisch nodules, kyphoscoliosis, tibial pseudoarthrosis, rib deformity, sphenoid wing dysplasia
  - < 10% of patients with neurofibroma have NF1

Demographics
- Age
  - 20-30 years
- Epidemiology
  - Schwannoma and neurofibroma: ~ 15% of all benign soft tissue tumors
    - 6% of soft tissue tumors superficial to investing fascia

Treatment
- Surgical excision of symptomatic lesions
  - Complete resection with sparing of parent nerve
  - Incomplete resection with sparing of parent nerve to minimize neurological impairment
  - Complete resection with excision of parent nerve
    - Autologous nerve graft or biodegradable nerve conduit if defect > 20 mm

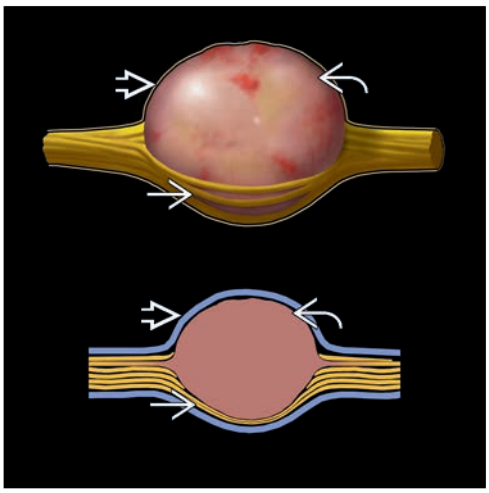
DIAGNOSTIC CHECKLIST

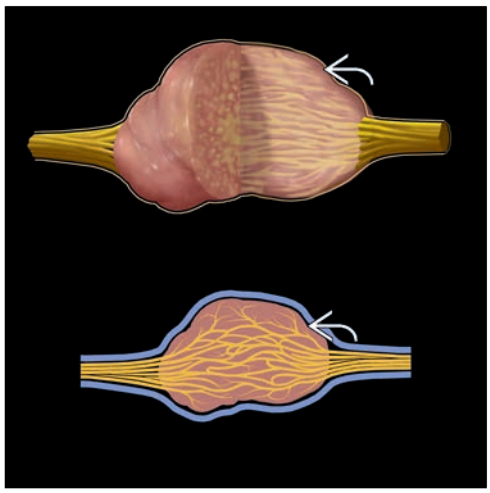
Consider
- Nerve sheath tumor, even if parent nerve not seen, provided other ultrasound features are compatible

SELECTED REFERENCES

1. Kubiena H et al: Peripheral neural sheath tumors (PNST)--what a radiologist should know. Eur J Radiol. 82(1):51-5, 2013

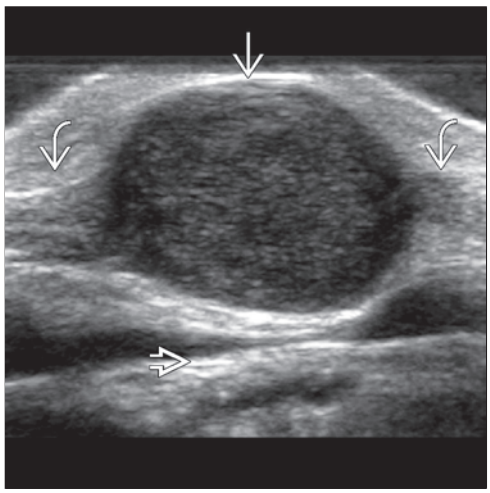
PERIPHERAL NERVE SHEATH TUMOR



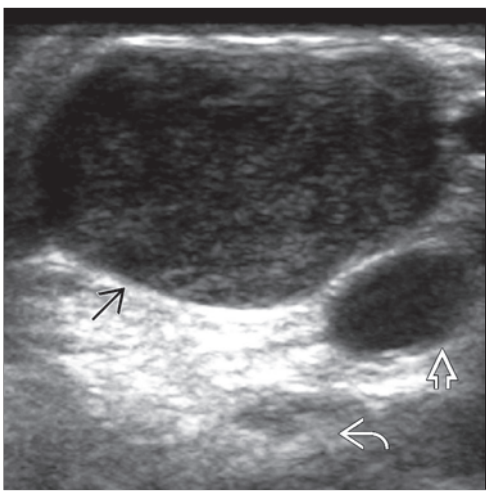


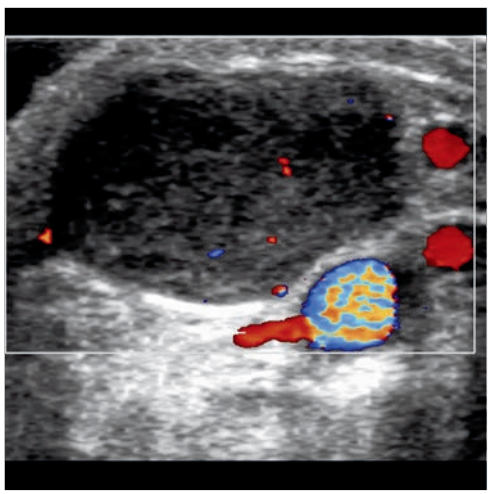
(Left) *Schematic shows a schwannoma. Each nerve is composed of axons arranged into fascicles. Each axon is covered by a myelin sheath composed of Schwann cells from which schwannoma derive. Each fascicle is covered by perineurium. All the fascicles are covered by epineurium.* ***(Right)*** *Schematic shows a neurofibroma. Neurofibromas also probably arise within nerve fascicles, but the cell of origin differentiates into different neural & perineural cell elements instead of a Schwann-cell type.*





(Left) *Clinical photo shows a focal swelling at the radial & volar aspect of the wrist region. Tinel sign was positive.* ***(Right)*** *Longitudinal ultrasound of the same patient shows a well-defined, quite homogeneous, ovoid hypoechoic mass continuous with the superficial sensory branch of the radial nerve. There is moderate posterior acoustic enhancement.*

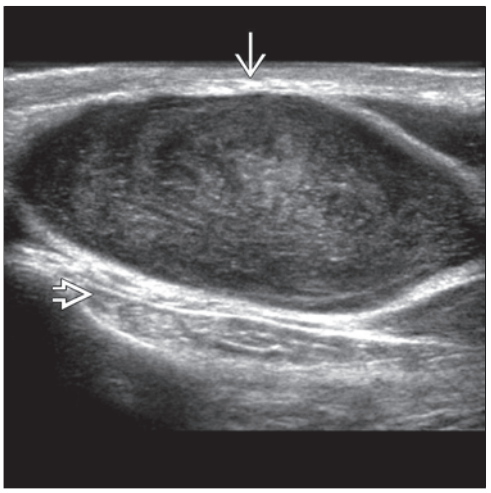


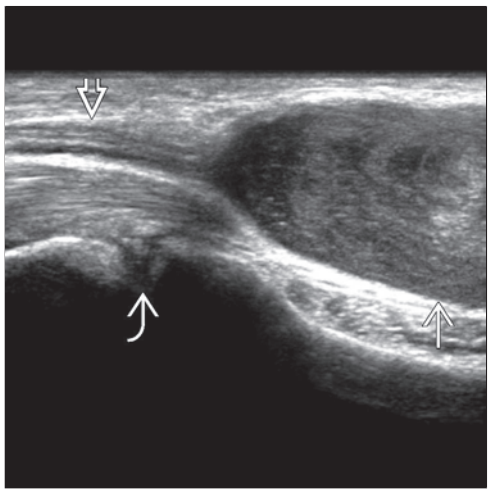


(Left) *Transverse ultrasound of the same tumor shows the mass to be in close proximity to the radial artery. Moderate posterior acoustic enhancement is present.* ***(Right)*** *Transverse color Doppler ultrasound of the same tumor shows mild intratumoral vascularity. The mass is arising from the radial neurovascular bundle and abutting the radial artery & veins. These findings are entirely consistent with a nerve sheath tumor of the radial nerve.*

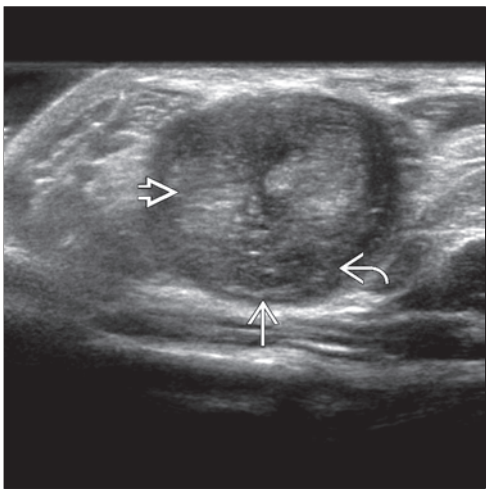
PERIPHERAL NERVE SHEATH TUMOR

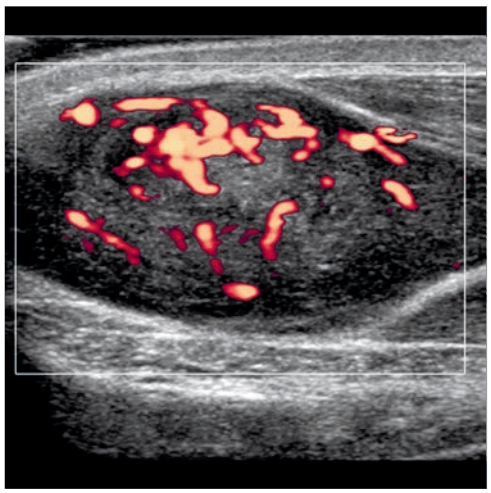
(Left) *Longitudinal ultrasound shows a fusiform-shaped hypoechoic mass and posterior acoustic enhancement on the ventral aspect of the distal forearm.* ***(Right)*** *Longitudinal ultrasound of the same tumor shows the mass arising from the median nerve proximal to the carpal tunnel in the distal forearm. The median nerve is slightly thickened. Note the radiocarpal articulation. The tumor was pathologically proven to be a schwannoma.*



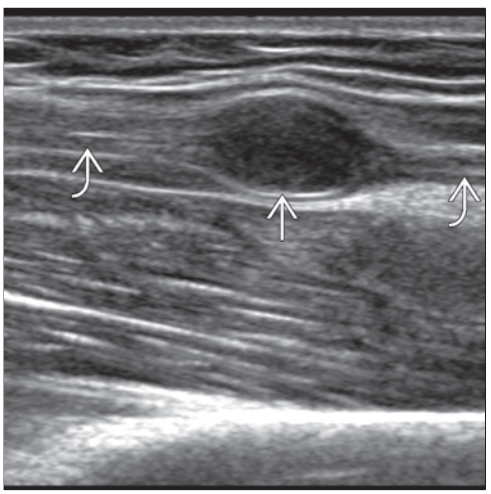


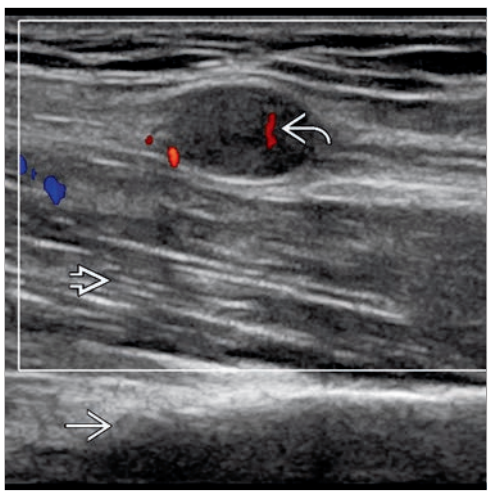
(Left) *Transverse ultrasound of the same tumor shows tumoral internal heterogeneity. Internal heterogeneity is due to a juxtaposition of hypoechoic fibrocollagenous tissue and hypoechoic myxoid tissue. This tissue variability also leads to the variable vascularity seen on color Doppler imaging.* ***(Right)*** *Longitudinal power Doppler of the same tumor shows moderate intratumoral vascularity consistent with a relatively high fibrocollagenous content.*



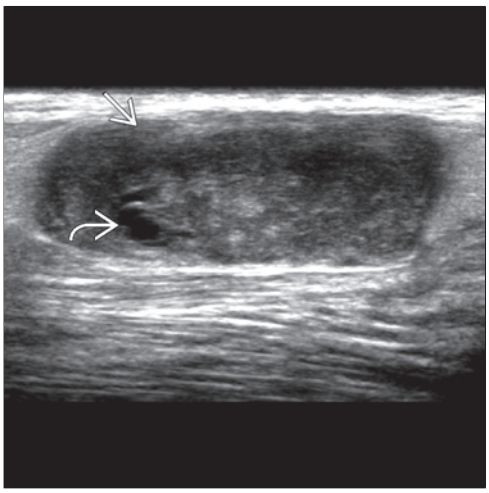


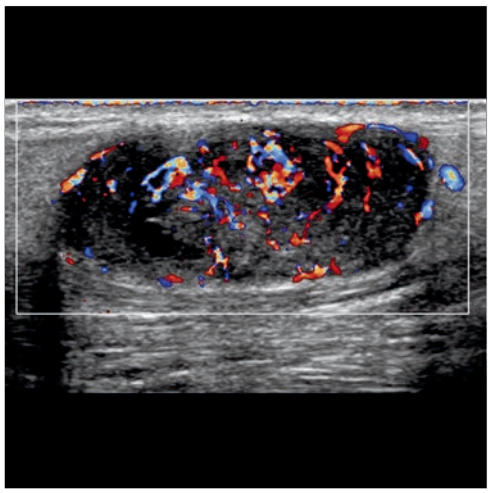
(Left) *Longitudinal ultrasound shows a small nerve sheath tumor of the median nerve in the distal arm region. Note the entering & exiting nerve components of the median nerve.* ***(Right)*** *Longitudinal color Doppler ultrasound of the same lesion shows mild intratumoral vascularity. Note the arm muscles and humerus. The vascularity of nerve sheath tumors does vary but usually some degree of vascularity is present.*



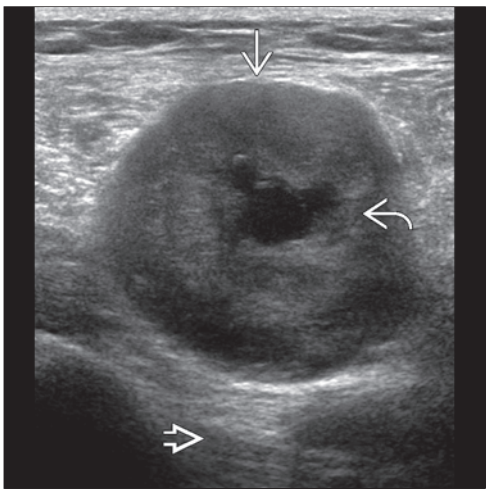


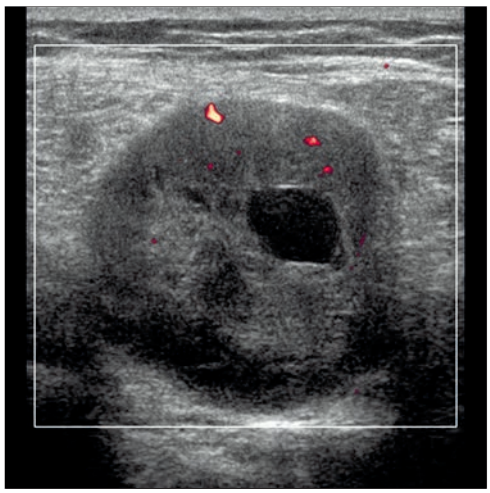
PERIPHERAL NERVE SHEATH TUMOR



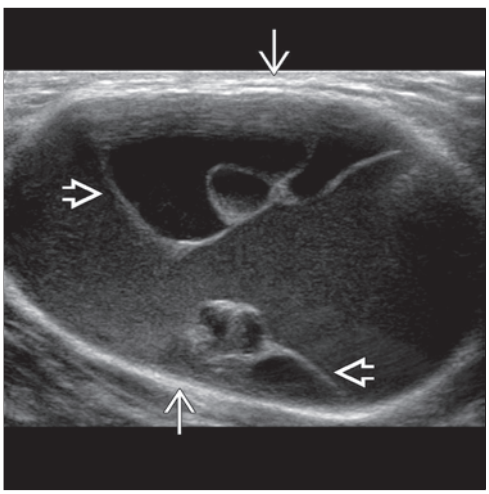


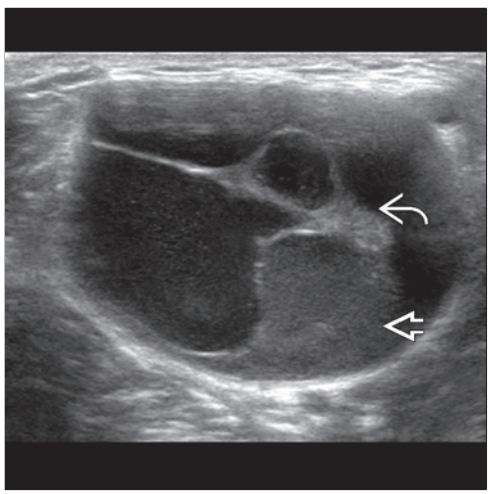
(Left) *Longitudinal ultrasound shows a well-defined, hypoechoic, oval-shaped nerve sheath tumor within the peroneus brevis muscle with some myxoid areas. Moderate posterior acoustic enhancement is present. No neural tail is present as this histologically confirmed schwannoma is arising from a small intramuscular nerve.* ***(Right)*** *Longitudinal color Doppler ultrasound of the same tumor shows moderate to high intratumoral vascularity.*





(Left) *Transverse ultrasound of the upper thigh region shows a well-defined schwannoma arising from the sciatic nerve with a central myxoid-type area. Moderate posterior acoustic enhancement is present.* ***(Right)*** *Transverse color Doppler ultrasound of the same tumor shows minimal intrinsic vascularity. Cystic change due to myxoid accumulation, hemorrhage, or necrosis is more commonly seen in schwannoma than neurofibromas.*

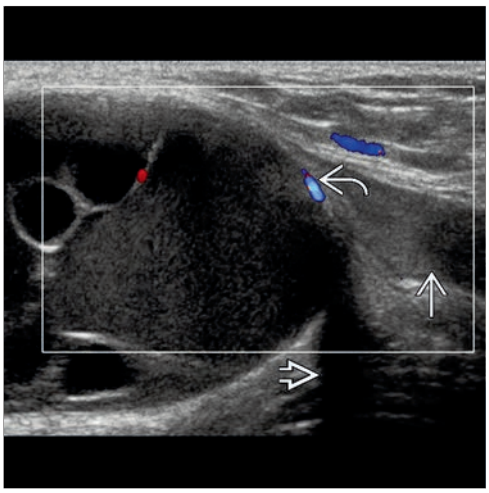




(Left) *Longitudinal ultrasound shows a well-defined, multiseptated cystic tumor in the axillary region. Note the multiple thin septations within the cystic mass. Very little solid tissue is present.* ***(Right)*** *Transverse ultrasound of the same tumor shows the presence of a small solid component within the tumor. Low-level echoes present in the dependent portion of the lesion are most likely due to previous hemorrhage.*

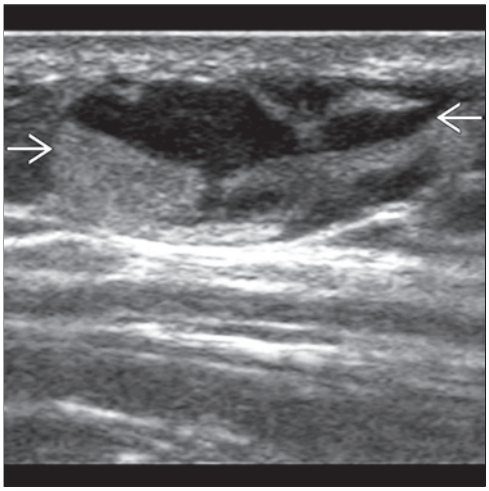
PERIPHERAL NERVE SHEATH TUMOR

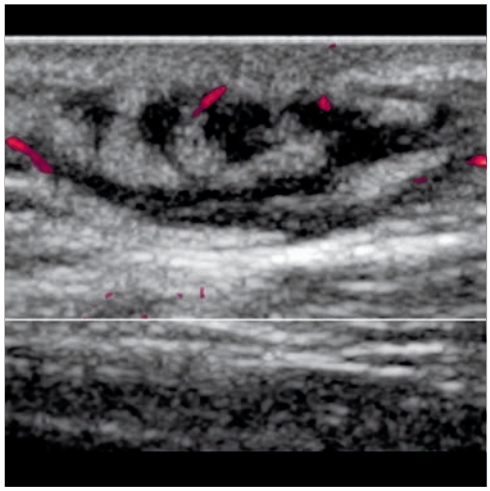
(Left) *Longitudinal color Doppler ultrasound of the same tumor shows that it is eccentrically related to the median nerve. Mild peripheral vascularity is present along with edge shadowing.* ***(Right)*** *Oblique coronal T2WI FS MR of the same tumor shows the cystic mass with continuity of the median nerve. Pathology revealed a cystic schwannoma. This type of cystic schwannoma is sometimes referred to as an ancient schwannoma.*



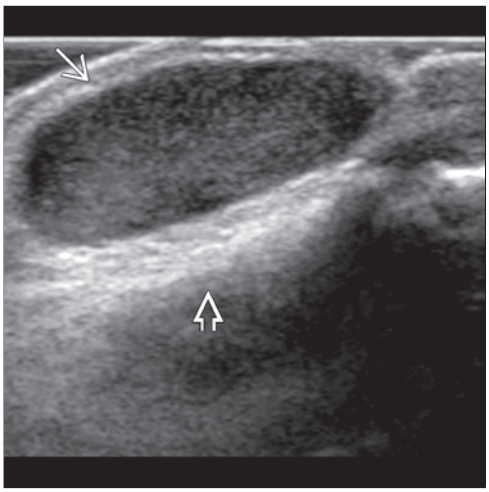


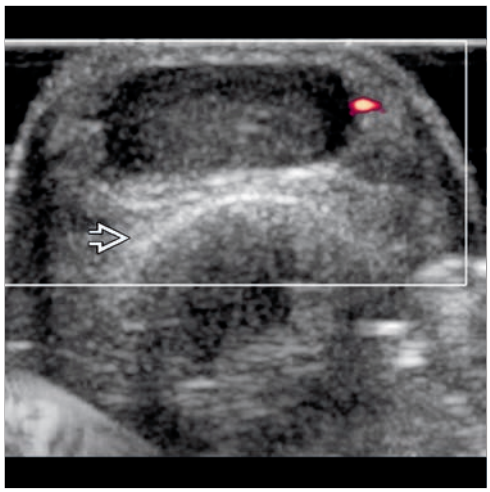
(Left) *Longitudinal ultrasound shows a well-defined mixed cystic & solid lesion present in the subcutaneous layer of the midforearm. No neural thickening was present adjacent to this mass.* ***(Right)*** *Transverse power Doppler ultrasound of the same tumor shows minimal tumoral vascularity. Pathology revealed this to be a localized neurofibroma with atypical features. Cyst-like areas can be seen in neurofibroma but are more common in schwannoma.*



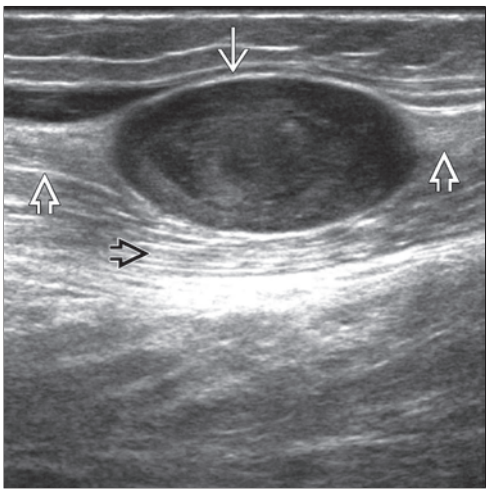


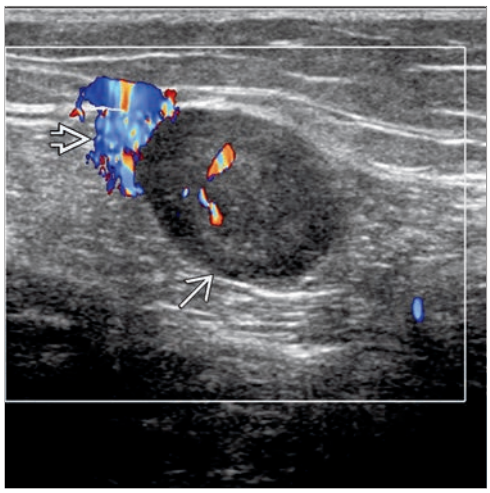
(Left) *Longitudinal ultrasound shows a well-defined, cystic-looking mass with posterior acoustic enhancement on the dorsal aspect of ring finger. Note the proximal phalanx.* ***(Right)*** *Transverse power Doppler ultrasound shows no intrinsic intratumoral vascularity superficial to the extensor tendon. The lesion was considered on ultrasound to be a ganglion or epidermoid cyst but was pathologically proven to be a nerve sheath tumor.*



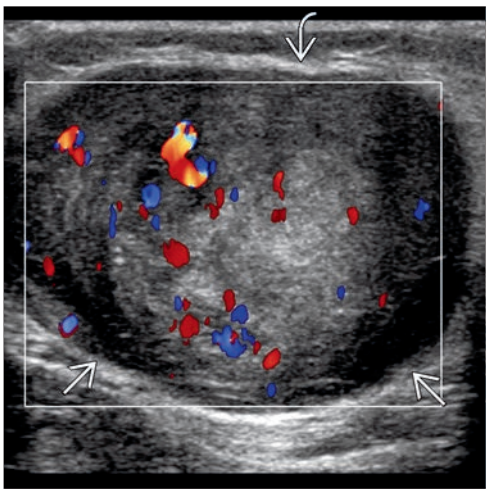


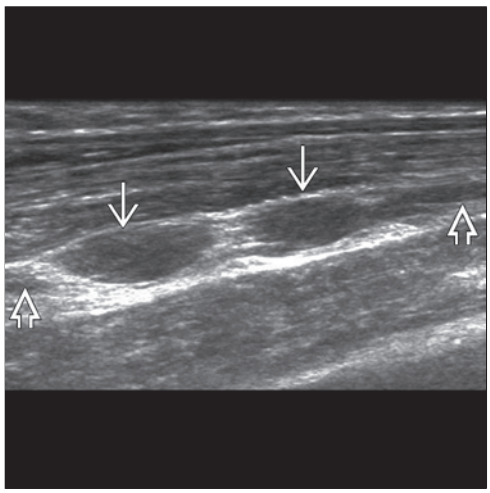
PERIPHERAL NERVE SHEATH TUMOR





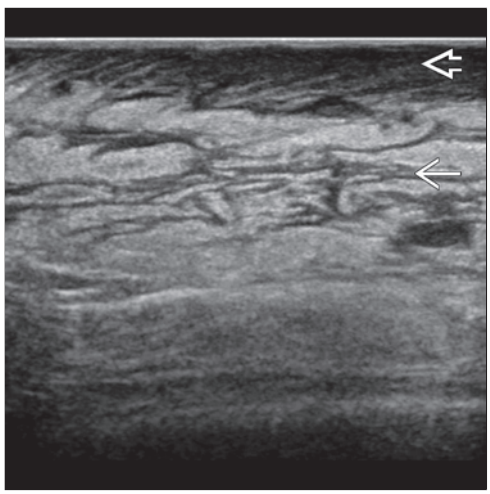
(Left) *Longitudinal ultrasound of a patient with NF1 shows a nerve sheath tumor with characteristic appearances in the medial thigh region. Continuity with the parent nerve and moderate posterior enhancement is present.* ***(Right)*** *Transverse color Doppler ultrasound of the same tumor shows mild intratumoral vascularity. The nerve sheath tumor is located alongside the medial thigh vessels.*





(Left) *Transverse color Doppler ultrasound of the same patient with NF1 shows a nerve sheath tumor located between the vastus medialis & intermedialis muscles. There is moderate intrinsic vascularity and a peripheric echogenic rim due to compressed peritumoral fat.* ***(Right)*** *Longitudinal ultrasound of the forearm of the same patient shows 2 nerve sheath tumors along the ulnar nerve. Multiple nerve sheath tumors are associated with NF1.*

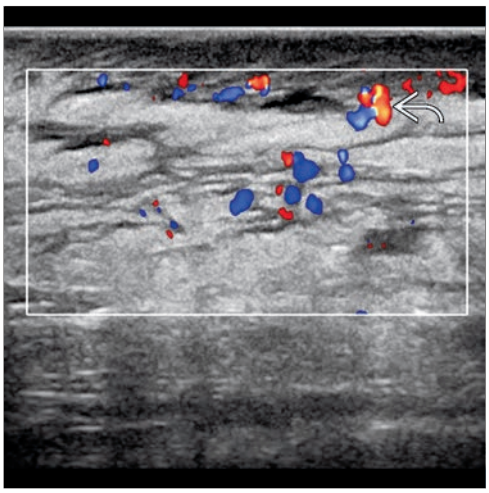


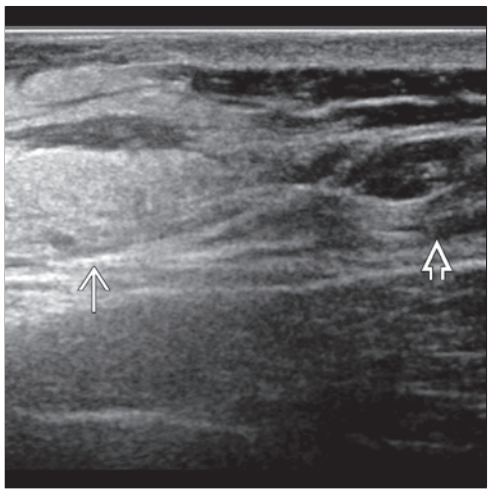


(Left) *Clinical photo of an NF1 patient shows a large swelling in the posterolateral chest wall and a smaller swelling close to the midline. There are multiple café au lait spots.* ***(Right)*** *Longitudinal ultrasound of the larger swelling shows a large, poorly defined infiltrative area of skin and subcutaneous tissue thickening. No discrete mass is apparent on ultrasound.*

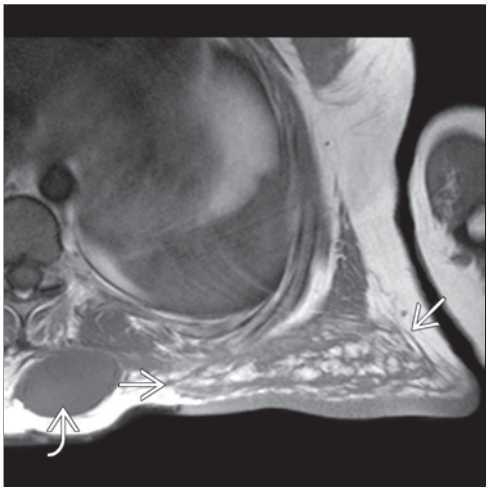
PERIPHERAL NERVE SHEATH TUMOR

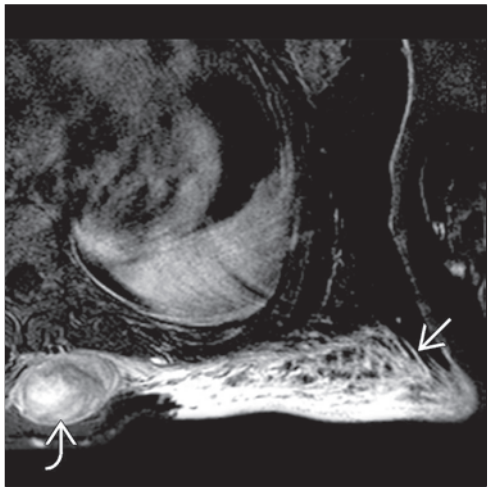
(Left) *Longitudinal color Doppler ultrasound of the same lesion shows moderate hyperemia. The appearances are those of an infiltrative diffuse neurofibroma, confirmed by percutaneous biopsy and histology.* ***(Right)*** *Longitudinal ultrasound of the same area of diffuse neurofibroma shows the quite abrupt zone of transition between normal-looking hypoechoic subcutaneous fat and the hyperechoic tissue of diffuse neurofibroma.*





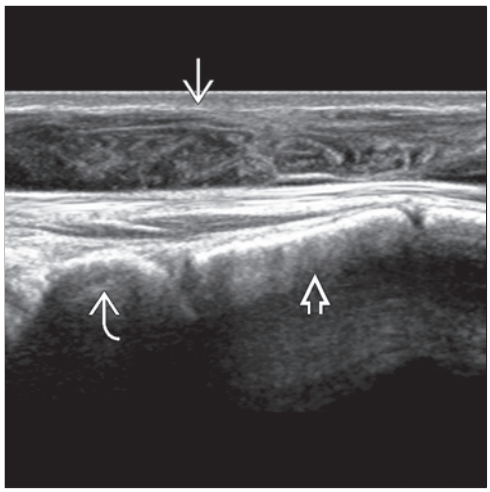
(Left) *Axial T1WI MR of the same diffuse neurofibroma shows an area of diffuse cutaneous & subcutaneous tissue thickening of the chest wall. Note the T1-hypointense localized neurofibroma present dorsal to the thoracic spine.* ***(Right)*** *Axial T1WI C+ digital subtraction MR shows avid, reticular-like enhancement in the chest wall lesion consistent with diffuse neurofibroma. Note the adjacent moderately enhancing localized neurofibroma.*

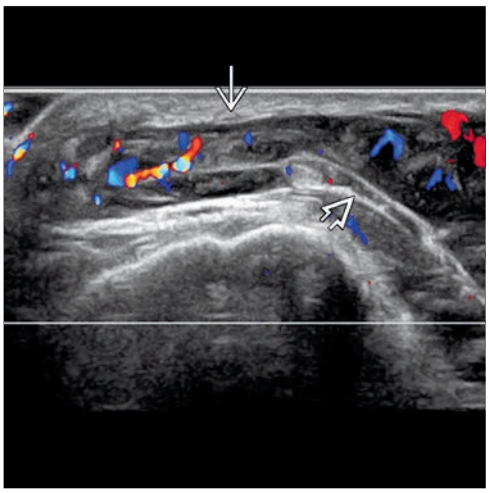


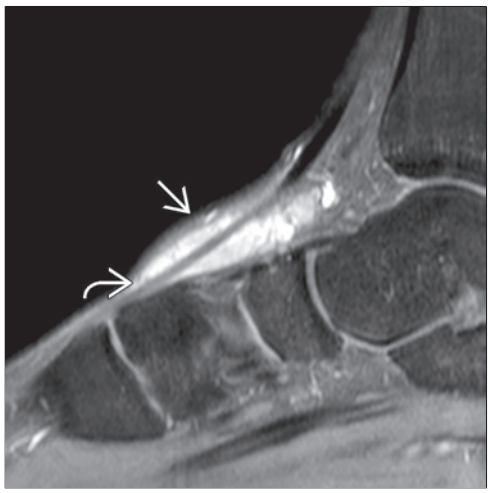


(Left) *Clinical photo of the dorsum of the foot of a patient with NF1 shows a localized swelling over the dorsal foot & ankle. Note the multiple small skin nodules in keeping with neurofibromatosis.* ***(Right)*** *Longitudinal ultrasound of the same swelling shows a diffuse hypoechoic mass lesion with "bag of worms" appearances on the dorsal aspect of foot. This is consistent with a plexiform neurofibroma. It is overlying the navicular and medial cuneiform bones.*



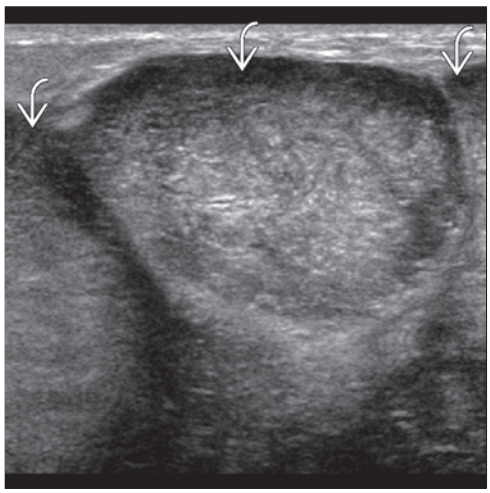




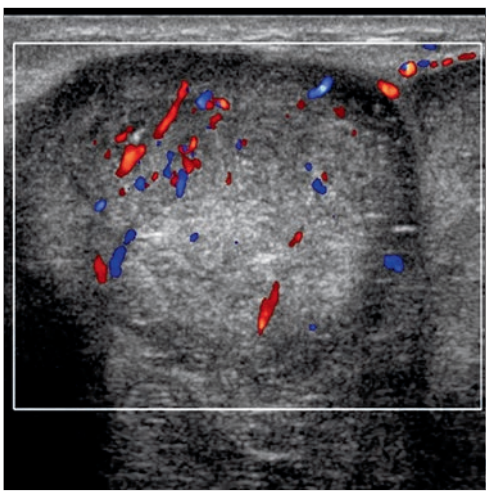


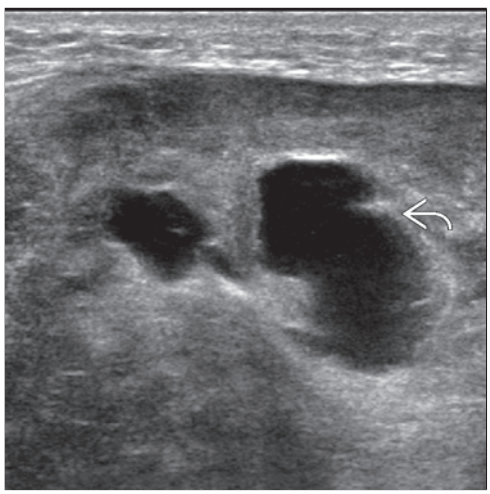
(Left) *Transverse color Doppler ultrasound of the same plexiform neurofibroma shows moderate intratumoral hyperemia* ➔. *The tumor is encasing the extensor hallucis longus tendon* ➔. ***(Right)*** *Sagittal T1WI C+ FS MR of the same plexiform neurofibroma shows avid tumoral enhancement* ➔, *which encases the extensor tendon* ➔. *Plexiform neurofibroma is diagnostic of NF1 and associated with a high risk of malignant change.*





(Left) *Clinical photo shows a large swelling* ➔ *on the dorsal aspect of the distal leg region with associated skin discoloration. This mass had been slowly growing for several years. A suitable site for biopsy has been marked on the skin.* ***(Right)*** *Transverse ultrasound of the same swelling shows part of a large, lobulated, solid hypoechoic mass* ➔ *in the anterior compartment of the leg. Only a part of the tumor can be depicted at a time by high-resolution ultrasound.*

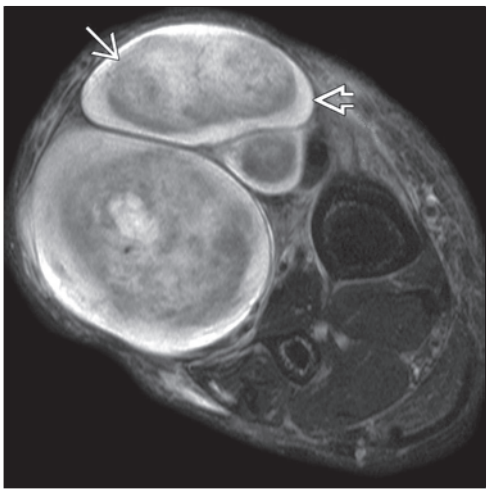


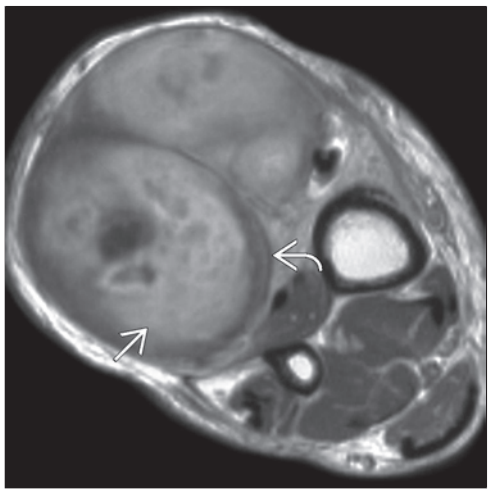


(Left) *Transverse color Doppler ultrasound of the same tumor shows moderate intratumoral hyperemia.* ***(Right)*** *Transverse ultrasound of another part of the same tumor shows a large myxoid-like area* ➔. *Biopsy revealed a cystic schwannoma. As there was concern regarding malignant change, the mass was subsequently excised, and pathology concurred fully with the earlier biopsy result.*

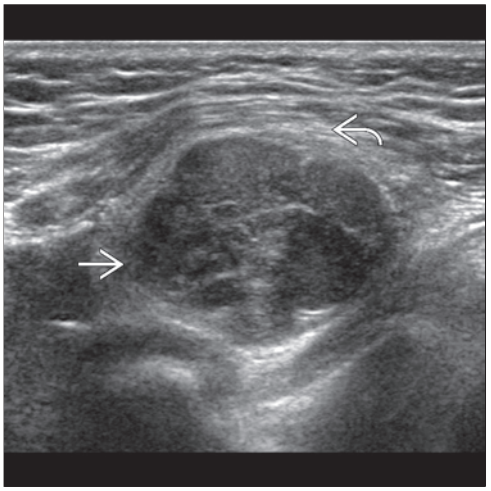
PERIPHERAL NERVE SHEATH TUMOR

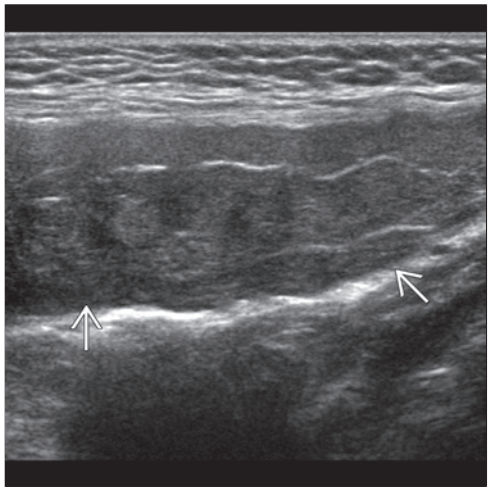
(Left) *Transverse T2WI FS MR of the same schwannoma prior to excision shows a large, lobulated mass with each lobule displaying a "target" sign due to more centralized hypointense fibrous component and a more peripheral hyperintense myxoid component.* ***(Right)*** *Transverse T1W1 C+ FS MR of the same tumor shows a "reverse target" sign characterized by enhancement of the central fibrous component and lack of enhancement of the surrounding myxoid component.*



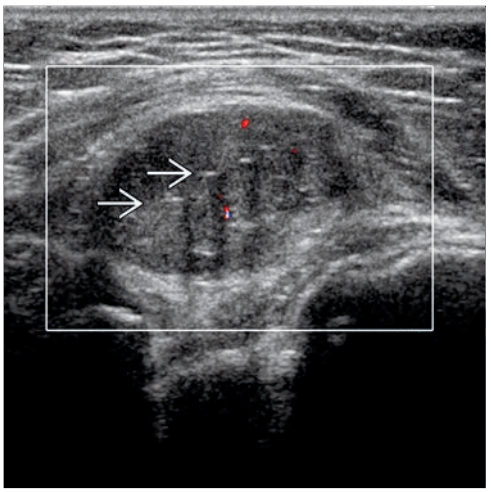


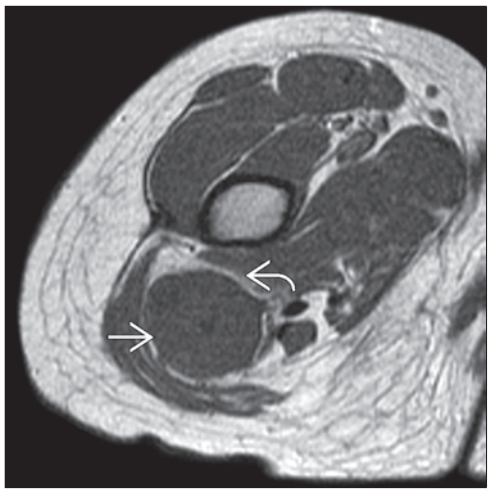
(Left) *Transverse ultrasound of the posterior thigh in a 3-year-old female with a short history of posterior thigh swelling and limping gait shows a multilobulated hypoechoic swelling with posterior enhancement of the sciatic nerve. Note the echogenic rim around the mass due to the compressed fat.* ***(Right)*** *Longitudinal ultrasound shows the same sciatic nerve diffusely and severely thickened.*



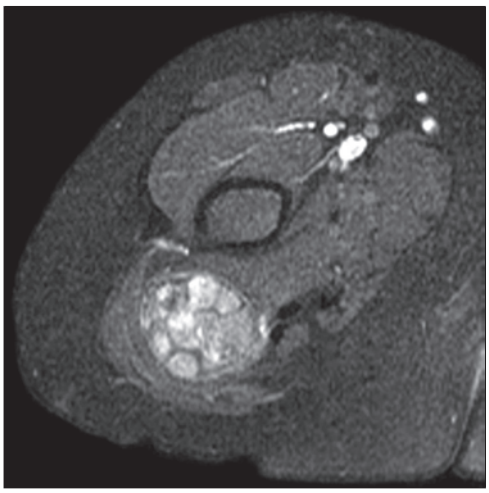


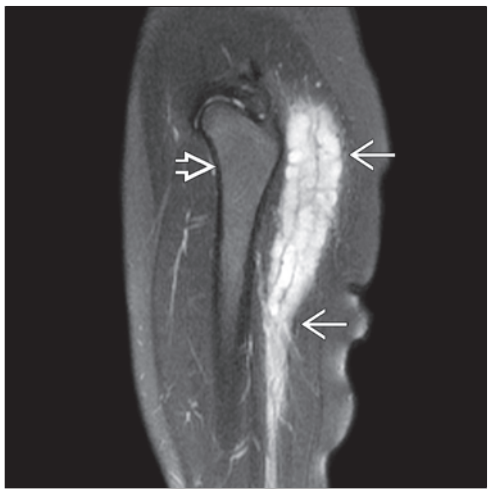
(Left) *Transverse color Doppler ultrasound of the same thickened sciatic nerve shows mild intralesional hyperemia. Several small intratumoral echogenic foci with acoustic shadowing can be more easily appreciated on this image.* ***(Right)*** *Axial T1WI MR of the same lesion shows the thickened isointense sciatic nerve. There is a thin rim of hyperintense fat surrounding the tumor. There is no local invasion. This child was otherwise well with no features of NF1.*



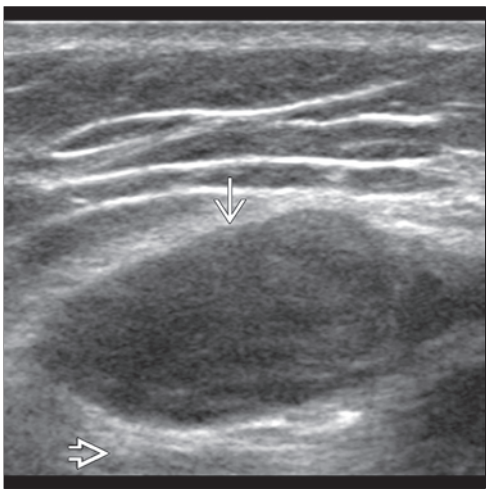


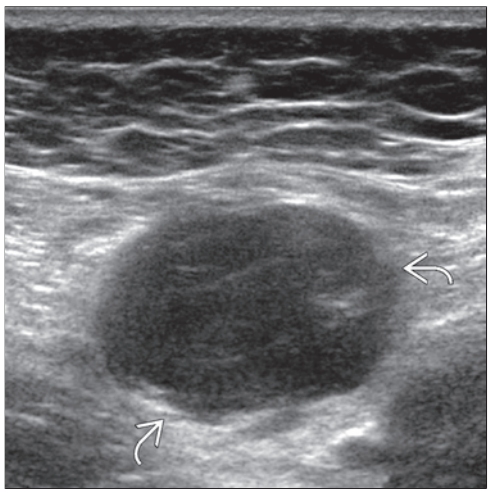
PERIPHERAL NERVE SHEATH TUMOR



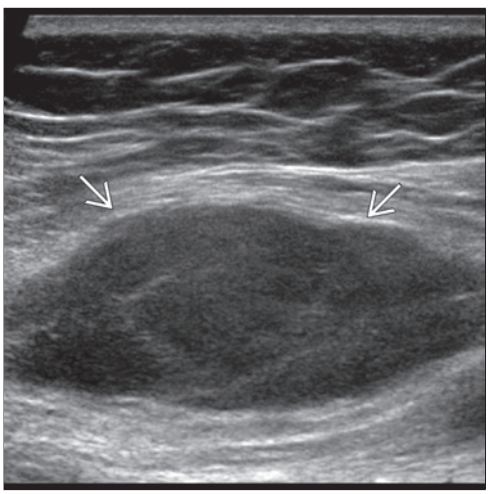


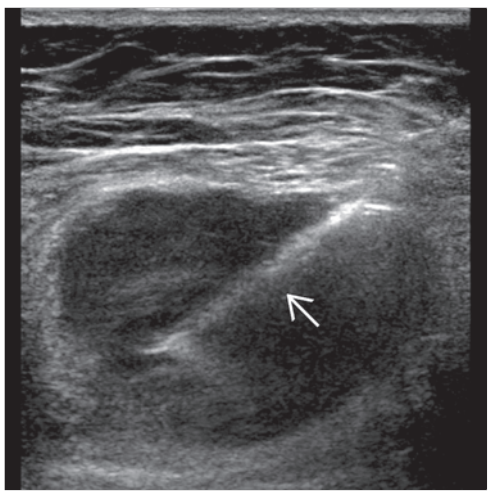
(Left) *Transverse T1WI C+ FS MR of the same lesion shows moderate intratumoral contrast enhancement. Note the fascicular appearance of the tumor.* ***(Right)*** *Sagittal T2WI FS MR of the same lesion shows severe, diffuse sciatic nerve enlargement posterior to the femur. The appearances are those of a nerve sheath tumor. Pathology revealed a malignant nerve sheath tumor. Benign & malignant nerve sheath tumors share similar imaging features.*





(Left) *Longitudinal ultrasound shows a fusiform hypoechoic nerve sheath tumor along the radial nerve in the posterior arm region. Note the posterior acoustic enhancement.* ***(Right)*** *Transverse ultrasound of the same tumor shows the slightly irregular tumor border. Clinically, the mass was enlarging, so a follow-up ultrasound examination was arranged 6 months later. There were no clinical features of NF1.*





(Left) *Follow-up longitudinal ultrasound of the same tumor 6 months later shows mild to moderate interval increase in tumor size.* ***(Right)*** *Transverse ultrasound of the same tumor shows moderate increase in tumor size, particularly in the transverse plane. Rapid irregular growth is an indicator of malignant transformation of nerve sheath tumor. The tumor was biopsied and shown to be a malignant nerve sheath tumor.*

CARPAL TUNNEL SYNDROME

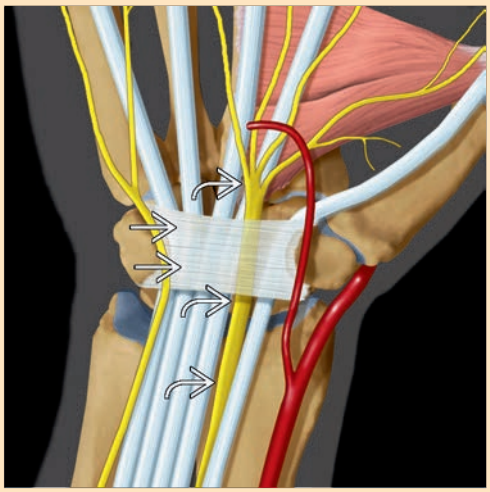
Key Facts

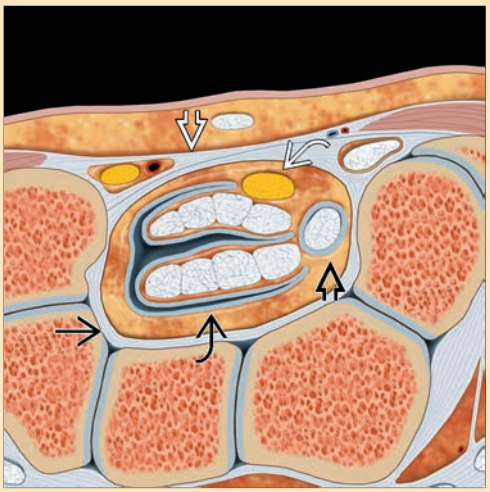
Terminology
- Symptoms secondary to compression of median nerve in carpal tunnel area
- Most common entrapment neuropathy

Imaging
- The more swollen the median nerve proximal to or within the carpal tunnel, the more likely the possibility of carpal tunnel syndrome (CTS)
- Measure nerve cross-sectional area (CSA) at proximal end of pronator quadratus (CSAp) as well as immediately proximal to tunnel, tunnel inlet, & tunnel outlet (CSAc)
- 2 main measurement methods
- **Largest CSA**
  - Median nerve CSA ≥ 12 mm² at any measurement point is strong positive predictor of CTS
  - Median nerve CSA ≤ 9 mm² at all measurement points is strong negative predictor of CTS
- **Relative increase in nerve CSA**
  - Calculate difference between CSAp & largest carpal tunnel measurement (CSAc)
  - If CSAc - CSAp > 4 mm², this is a positive predictor of CTS
- Additional ultrasound signs of CTS have reduced discriminatory power if used in isolation though may improve discrimination when used with CSA measurements
  - Intraneural hyperemia, neural edema
  - Altered median nerve movement on dynamic ultrasound testing
  - Retinacular bowing, flattening ratio

Clinical Issues
- Night tingling & pain radial 3 1/2 digits
- Positive Tinel & Phalen signs

(Left) *Graphic shows the median nerve deep to the flexor retinaculum & superficial to the flexor tendons. The nerve usually divides just beyond the tunnel outlet.* ***(Right)*** *Schematic axial view of the carpal tunnel shows the median nerve lies immediately below the flexor retinaculum & superficial to the flexor digitorum tendons, which are surrounded by the ulnar bursa & the flexor pollicis longus, which is surrounded by the radial bursa. The extrinsic ligaments lie above the carpal bones.*





(Left) *Transverse ultrasound of the median nerve just proximal to the carpal tunnel inlet shows enlargement (15 mm²) . A nerve CSA > 12 mm² is a positive predictor for CTS. Note also the loss of neural fascicular structure, which is an additional sign of CTS.* ***(Right)*** *Transverse ultrasound of same patient shows CSA measurement by continuous tracing around nerve perimeter. As the nerve is occasionally irregular in outline, electronic tracing can achieve better results than ellipsoid calipers.*





CARPAL TUNNEL SYNDROME

TERMINOLOGY

Abbreviations
- Carpal tunnel syndrome (CTS)

Definitions
- Symptoms secondary to compression ± ischemia of median nerve in carpal tunnel area
  - Most common entrapment neuropathy

IMAGING

General Features
- Best diagnostic clue
  - Swollen median nerve proximal to or within carpal tunnel
- Size
  - Nerve cross-sectional area (CSA) varies from 5 mm² to > 25 mm²
- Morphology
  - Hourglass-type appearance of median nerve due to compression in carpal tunnel with swelling proximally & distally

Ultrasonographic Findings
- Swelling of median nerve either proximal to or within carpal tunnel
  - The more swollen the median nerve, the more likely the possibility of CTS
  - Rigid criteria are not useful in clinical practice as median nerve compression is continuum rather than "all or none" phenomenon
- Measure CSA by tracing around nerve perimeter
  - Area predicted by measurement of width & depth is not as accurate as trace method
- 2 main measurement methods based on median nerve CSA, either of which can be used
  - **Largest CSA of nerve**
    - Median nerve CSA measured at 3 points: Immediately proximal to tunnel inlet, at tunnel inlet, & at tunnel outlet
    - Optimal cutoff point: Median nerve CSA ≥ 10 mm² in smaller patients, > 12 mm² in larger patients
    - Median nerve CSA ≥ 12 mm² at any measurement point: Strong positive predictor of CTS (sensitivity/specificity > 90%)
    - Median nerve CSA ≤ 9 mm² at all measurement points: Strong negative predictor of CTS (sensitivity/specificity > 90%)
  - **Relative increase in nerve CSA**
    - Median nerve CSA measured at proximal 1/3 of pronator quadratus muscle level (CSAp) & immediately proximal to tunnel inlet, at tunnel inlet, & at tunnel outlet (CSAc)
    - Difference between pronator quadratus level measurement (CSAp) & any carpal tunnel measurement (CSAc) should not be > 4 mm²
    - A difference between CSAc & CSAp (ΔCSA) of > 4 mm² is a strong positive predictor of CTS
- Increase in nerve caliber is, by far, the most reliable ultrasound criterion of CTA
- Additional US signs of CTS may ↑ diagnostic accuracy when combined with CSA measurements though, in isolation, each has lower discriminatory power
  - Not necessary to use these secondary signs routinely
- Additional US signs of CTS
  - Increased intraneural vascularity on color Doppler imaging
    - Hyperemia is a marker of neural inflammation & ischemia
  - Median nerve edema
    - Nerve becomes homogeneously hypoechoic with loss of the normal fascicular pattern
    - Prone to angle beam artifact (anisotropy) & difficult to quantify
  - Altered median nerve movement on dynamic US testing
    - ↓ longitudinal movement or ↑ volar dorsal movement between flexor tendons during wrist flexion leads to nerve becoming pinched
  - ↑ retinacular bowing
    - Increased volar convexity of transverse carpal ligament
  - Flattening ratio
    - Width:depth ratio > 3 of median nerve ↑ with CTS
  - Median nerve CSA just beyond tunnel outlet
    - Wide variation as nerve splits into digital branches
  - Thenar muscle atopy
    - Difficult to quantify on US
- Features of secondary CTS
  - Accessory muscle compressing carpal tunnel
    - Anomalous palmaris longus
      - Duplicated, hypertrophied, or reversed (i.e., fleshy in distal part, tendinous in proximal part)
    - Hypertrophied or bipennate lumbrical muscle
    - Anomalous flexor digitorum superficialis muscle belly
  - Flexor digitorum tenosynovitis
  - Ganglion, lipoma, or gouty tophus compressing carpal tunnel
  - Nerve sheath tumor of median nerve
  - Hamartomatous fibrolipoma of median nerve
  - Thrombosed persistent median artery
- Following carpal tunnel decompression
  - Useful to look for incomplete transection of transverse carpal ligament (flexor retinaculum)
  - Resected bands of retinaculum are wavy, thickened, & disposed obliquely on each side of nerve
  - Abrupt change in nerve caliber if continued compression
  - ± hypoechoic scar tissue encasing median nerve

MR Findings
- Swelling of median nerve
  - Hyperintense T2W signal intensity
- Synovium inflammation
  - Enhancing perineural soft tissue

Imaging Recommendations
- Best imaging tool
  - Ultrasound as it is accurate, quick, comfortable, & relatively inexpensive
- Protocol advice
  - Wrist supported on flat surface with fingers relaxed
    - Hand-wrist exercises should not precede examination as they may increase nerve caliber
  - High-resolution (≥ 10 MHz) linear transducer

CARPAL TUNNEL SYNDROME

- Measure nerve CSA at distal forearm, proximal to tunnel inlet, at tunnel inlet, & at tunnel outlet
- Try to keep transducer aligned at right angles to nerve rather than oblique
  - However, slight transducer angulation can utilize anisotropy to optimize delineation of nerve boundary
- Measure median nerve CSA by electronic tracing rather than ellipsoid calipers
- Perform measurements immediately after freezing image
- If median nerve bifid, measure both components separately, excluding any intervening median artery & summate
  - Same diagnostic parameters apply as for nonbifid median nerve
- Thenar muscle atrophy not usually assessed by ultrasound

DIFFERENTIAL DIAGNOSIS

Tenosynovitis

- Tendon sheath synovial proliferation & hyperemia predominates
  - ± secondary CTS

Inflammatory Synovitis

- Synovial swelling & hyperemia predominates
  - ± secondary CTS

PATHOLOGY

General Features

- Etiology
  - Due to compression ± microvascular ischaemia of median nerve in carpal tunnel
  - Majority primary with no specific structural cause found
  - Increased risk in
    - Females, > middle age, ↑ body mass index
    - Repetitive physical work
  - Secondary causes
    - Previous Colles fracture or carpal bone fracture, dislocation
    - Inflammatory wrist arthropathy
    - Pregnancy, estrogen replacement, diabetes, myxoedema
    - Tenosynovitis, anomalous muscles, ganglia, lipoma or nerve sheath tumor compressing carpal tunnel

Staging, Grading, & Classification

- No widely used grading scheme

Gross Pathologic & Surgical Features

- Inflammation & edema of median nerve

Microscopic Features

- Venous congestion, intrafascicular edema, endoneural & epineural swelling, wallerian degeneration, axonal damage

CLINICAL ISSUES

Presentation

- Most common signs/symptoms
  - Night tingling & pain in ≥ 1 radial 3 1/2 digits
    - Exacerbated by prolonged strenuous work or exercise
- Other signs/symptoms
  - Occasionally may affect ulnar 2 digits
  - ± abductor pollicis brevis & opponens pollicis weakness (early finding) followed by atrophy (late finding) = "ape hand"
- Clinical profile
  - Nocturnal exacerbation
    - Wrists tend to flex during sleep
  - Positive Tinel & Phalen signs
  - Electrodiagnostic studies (EDS) test functional integrity of nerve
    - Median nerve sensory conduction over 8 cm is compared to ipsilateral ulnar nerve sensory conduction over 8 cm
    - Main diagnostic parameter is median-ulnar sensory latency delay of > 0.5 ms
    - In population with high prevalence of CTS, specificity of EDS is > 90%

Demographics

- Age
  - Peak: 50 years ± 15 years
- Gender
  - M:F = 1:6
- Epidemiology
  - Cumulative lifetime prevalence rate: 10%
    - 0.5 million carpal tunnel decompressions performed yearly in USA

Natural History & Prognosis

- Symptoms usually remain over months or years
  - Tendency to improve clinically & electrophysiologically over time even without specific treatment
    - CTS will continue to progress in minority of patients

Treatment

- Conservative
  - Neutral position wrist splint
  - US-guided steroid injection into carpal tunnel
    - Symptom improvement for up to 12 weeks
- Surgical
  - Flexor retinaculum release; open vs. endoscopic, which may use ultrasound guidance

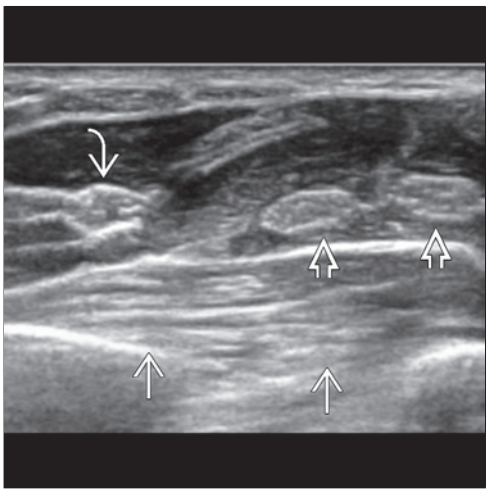
DIAGNOSTIC CHECKLIST

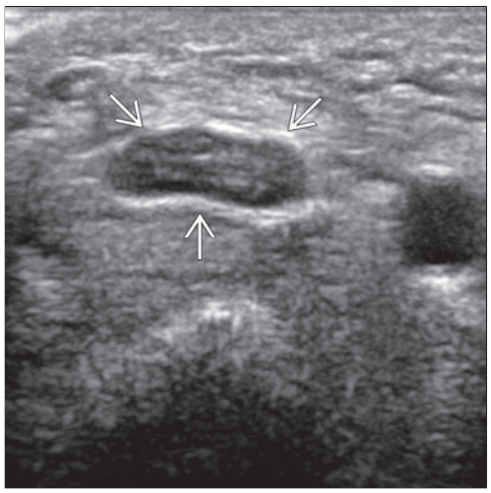
Consider

- CTS in all patients with unexplained hand, wrist, or distal forearm paresthesia ± pain, even though symptoms are atypical for CTS

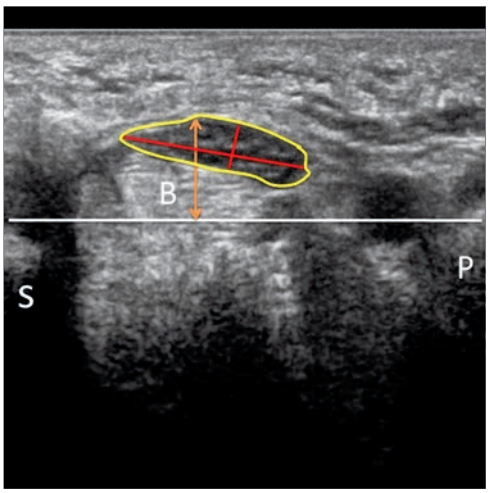
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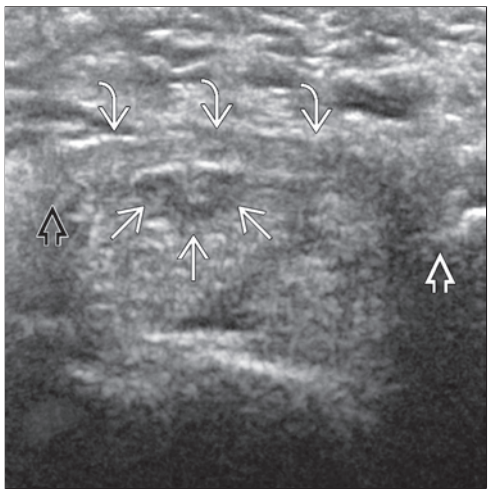
1. Klauser AS et al: Bifid median nerve in carpal tunnel syndrome: assessment with US cross-sectional area measurement. Radiology. 259(3):808-15, 2011



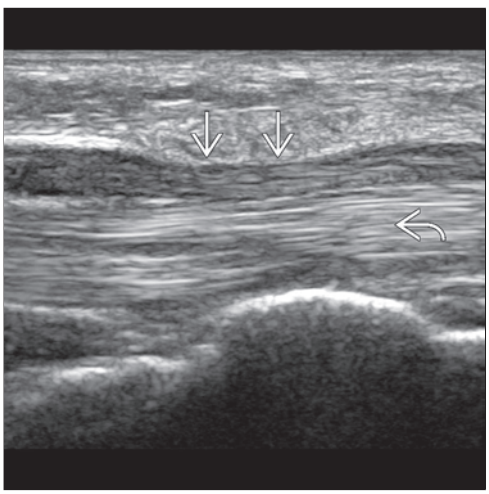


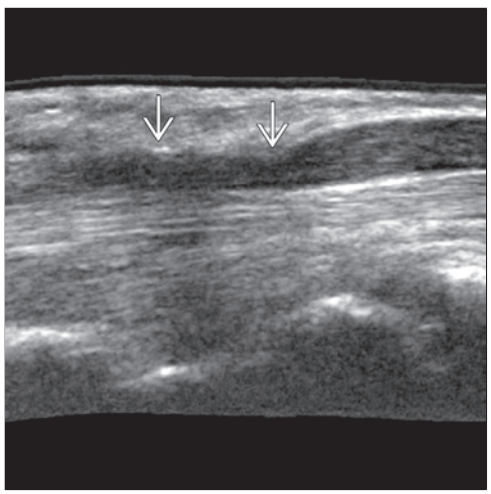
(Left) *Transverse ultrasound shows the normal appearance & size of the median nerve at the proximal end of the pronator quadratus muscle. At this location, the median nerve is ovoid in shape & not swollen. Note the adjacent flexor digitorum profundus tendons.* ***(Right)*** *Transverse ultrasound of the median nerve in the same patient just proximal to the carpal tunnel inlet shows the swollen median nerve with loss of normal fascicular nerve echopattern.*





(Left) *Transverse ultrasound of the median nerve at the inlet shows features of CTS with severe palmar retinaculum bowing (B) relative to the transverse carpal line drawn between scaphoid tubercle (S) & pisiform (P), high flattening ratio (red lines), & increased CSA of the median nerve (outlined by yellow).* ***(Right)*** *Transverse ultrasound of the carpal tunnel outlet at the level of hamate and trapezium show flattening of the median nerve with moderate retinaculum thickening.*



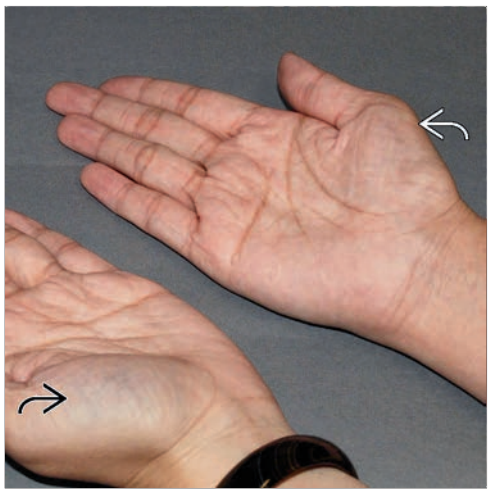


(Left) *Longitudinal ultrasound of the median nerve shows a mild hourglass configuration due to compression within the carpal tunnel. Note the underlying flexor tendons.* ***(Right)*** *Longitudinal ultrasound of the median nerve shows more severe abrupt change in nerve caliber at the inlet of the carpal tunnel consistent with severe compression. One can also appreciate the increased swelling of the medial nerve proximal to the carpal tunnel with loss of the normal fascicular pattern.*

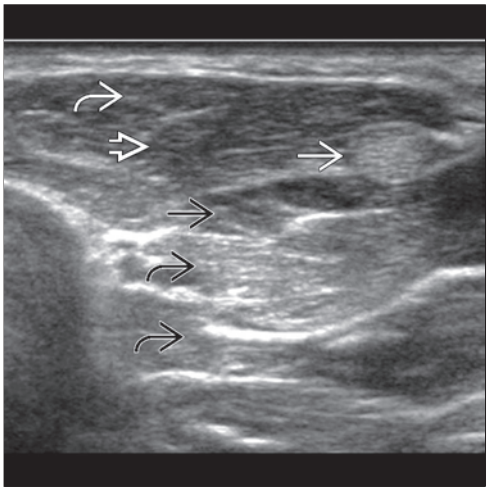
CARPAL TUNNEL SYNDROME

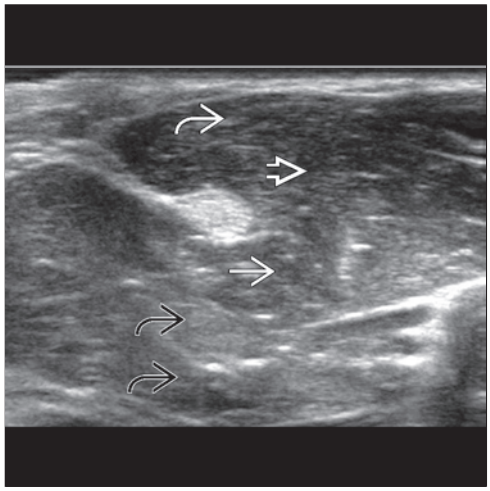
(Left) *Clinical photo of a patient with CTS shows moderate-severity atrophy of the thenar muscle, particularly affecting the abductor pollicis brevis muscle* ➔. ***(Right)*** *Clinical photo of another patient with CTS shows more severe, generalized atrophy of the thenar muscles* ➔ *on the right side. The normal contralateral thenar eminence* ➔ *is also shown for comparison. Thenar muscle atrophy is readily assessed clinically with no added benefit from ultrasound in this respect.*



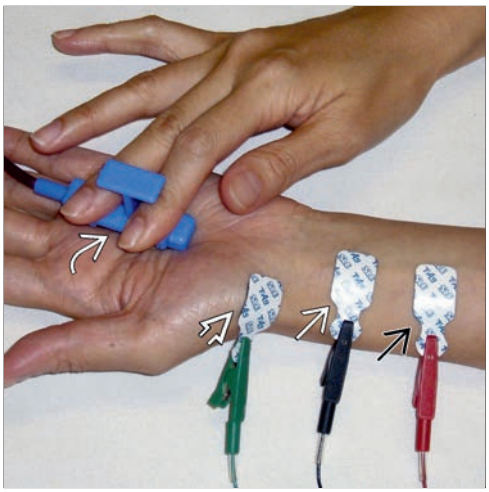


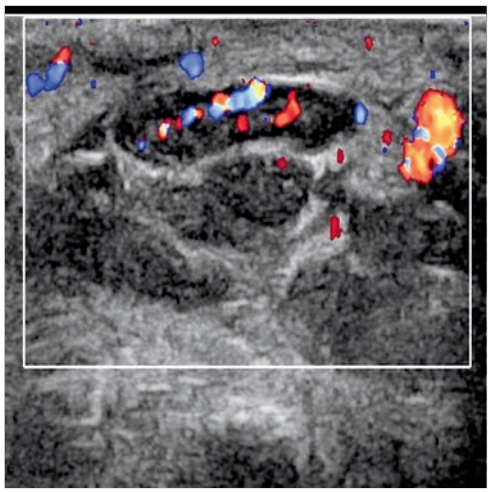
(Left) *Transverse US of a patient with CTS shows thenar muscle atrophy, including abductor pollicis brevis* ➔, *opponens pollicis* ➔, *flexor pollicis brevis* ➔, *& adductor pollicis* ➔ *muscles. Note the flexor pollicis longus tendon* ➔ *coursing between the thenar muscles.* ***(Right)*** *Transverse ultrasound of the contralateral side shows the normal bulky thenar muscle including the abductor pollicis brevis* ➔, *opponens pollicis* ➔, *flexor pollicis brevis* ➔, *& adductor pollicis* ➔ *muscles.*

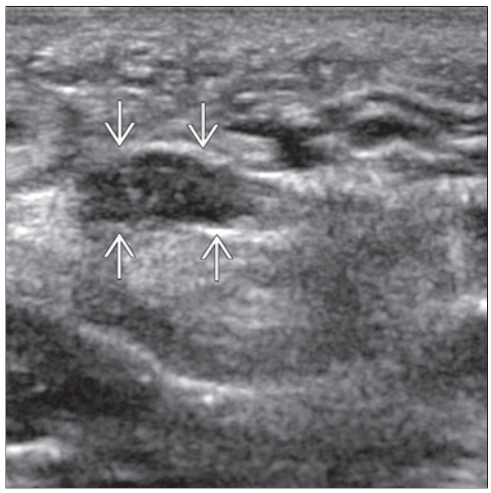




(Left) *Clinical photograph shows electrodiagnostic studies testing median nerve sensory conduction over 8 cm, with stimulating* ➔, *ground* ➔, *active recording* ➔, *& reference* ➔ *electrodes.* ***(Right)*** *Transverse color Doppler ultrasound shows moderate intraneural vascularity (hyperemia) proximal to the carpal tunnel in a patient with CTS. Intraneural hyperemia is a good positive predictor of CTS.*

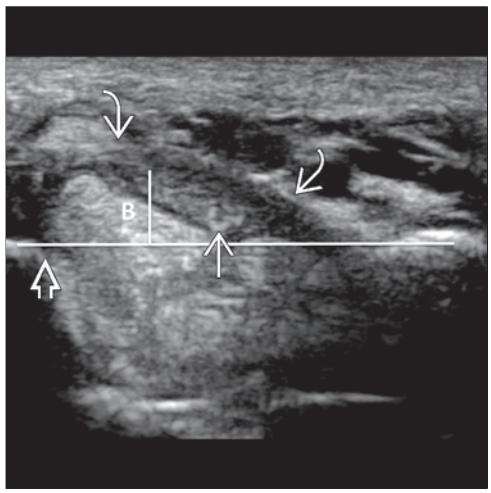


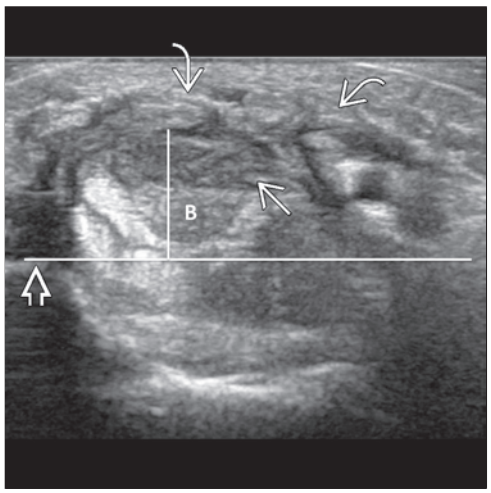




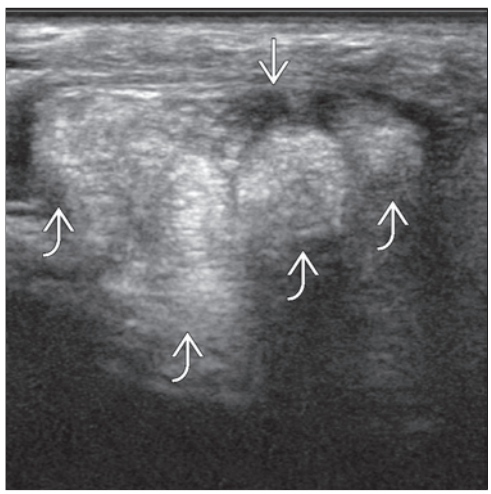


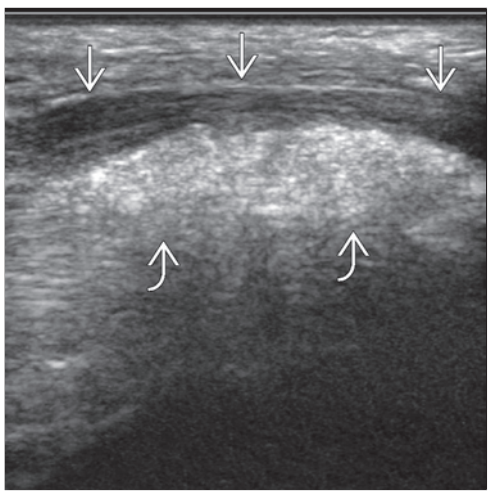
(Left) *Transverse ultrasound of the median nerve just distal to the tunnel outlet shows severe swelling of the median nerve, which has a homogeneous hypoechoic echopattern with loss of normal fascicular pattern* ➔. ***(Right)*** *Longitudinal ultrasound of the median nerve shows severe compression at an inlet level causing abrupt change in caliber with a notch sign* ➔ *& hourglass configuration to nerve. The flexor tendon deep to the median nerve is the flexor digitorum indicis* ➔.





(Left) *Transverse ultrasound of the carpal tunnel shows moderate palmar retinaculum bowing (B)* ➔ *relative to the transcarpal line* ➔. *Note that the median nerve* ➔ *is compressed at this level.* ***(Right)*** *Transverse ultrasound of the carpal tunnel inlet in the same patient after carpal tunnel release shows the cut margins* ➔ *of the transected retinaculum & satisfactory palmar bowing of the carpal tunnel (B) relative to the transverse carpal line* ➔. *The median nerve* ➔ *is swollen.*

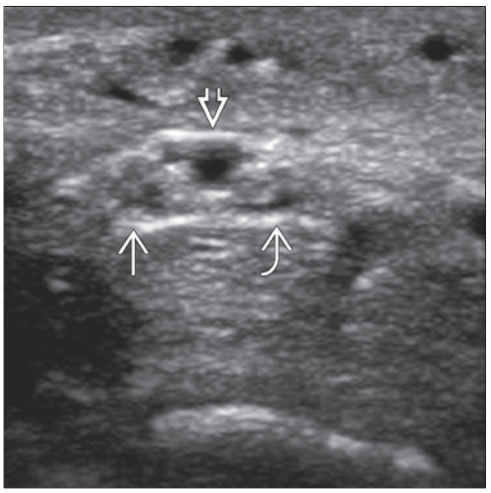


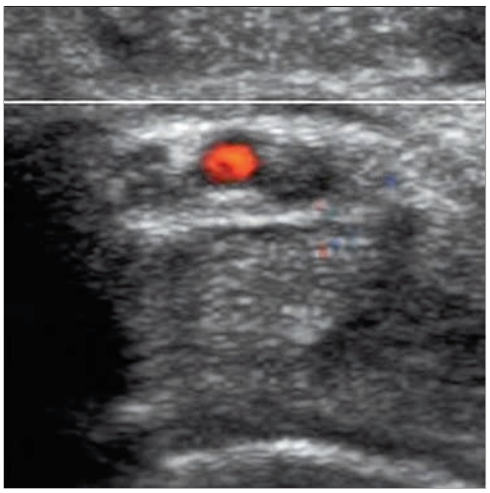


(Left) *Transverse ultrasound in a patient with CTS shows echogenic gouty tophi* ➔ *with posterior acoustic shadow within the carpal tunnel causing compression of the median nerve* ➔. *The flexor tendons cannot be clearly identified due to gouty crystal deposition.* ***(Right)*** *Longitudinal ultrasound of the same patient shows the median nerve* ➔ *being compressed within the carpal tunnel. The echogenic gouty tophi* ➔ *with posterior acoustic shadow are located deep to the median nerve.*

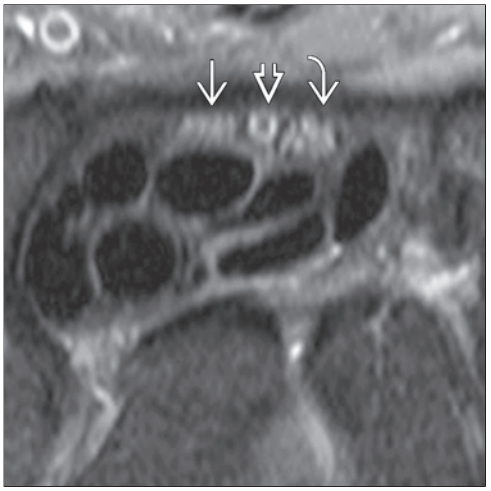
CARPAL TUNNEL SYNDROME

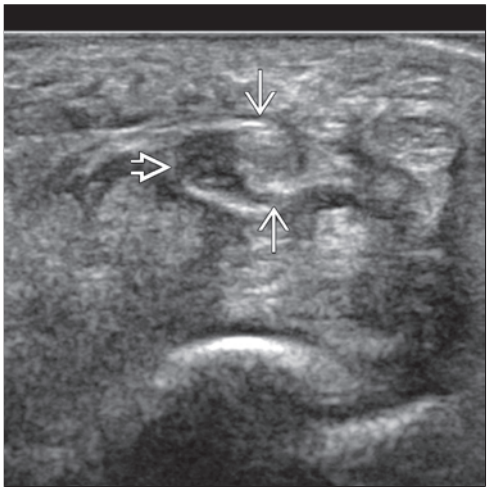
(Left) *Transverse ultrasound of the carpal tunnel inlet shows ulnar ➔ & radial ➔ components of the bifid median nerve associated with persistent median artery ➔ coursing in between these components. In this situation, the CSA of both components should be summated.* ***(Right)*** *Transverse power Doppler of the carpal tunnel inlet in the same patient shows normal arterial signal of persistent median artery. Thrombosis of this median artery is 1 cause of secondary CTS.*



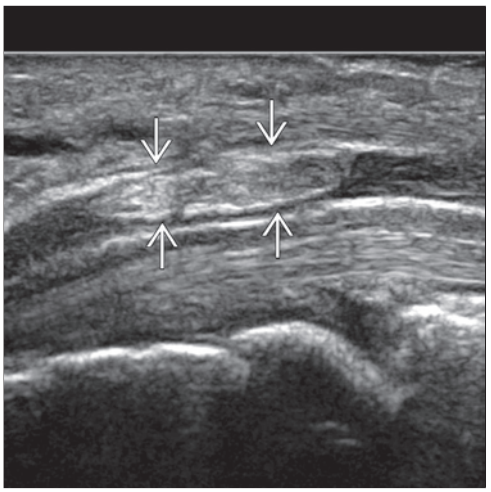


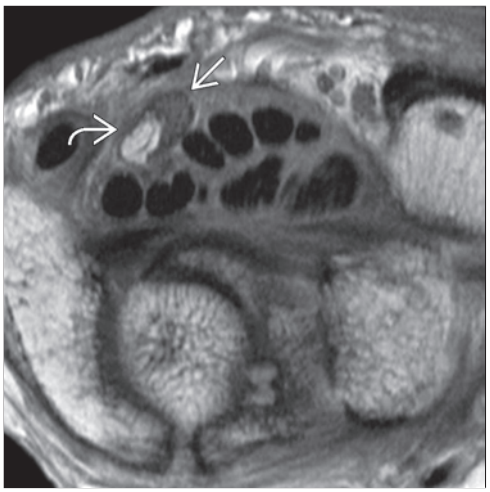
(Left) *Transverse PD FSE FS MR in the same patient at the carpal tunnel inlet shows ulnar ➔ & radial ➔ components of the bifid median nerve associated with a persistent median artery ➔ coursing in between the components.* ***(Right)*** *Transverse ultrasound of the median nerve at the midcarpal tunnel area in a patient presenting with CTS symptoms shows a well-defined echogenic mass ➔ present on the ulnar aspect of the median nerve ➔.*

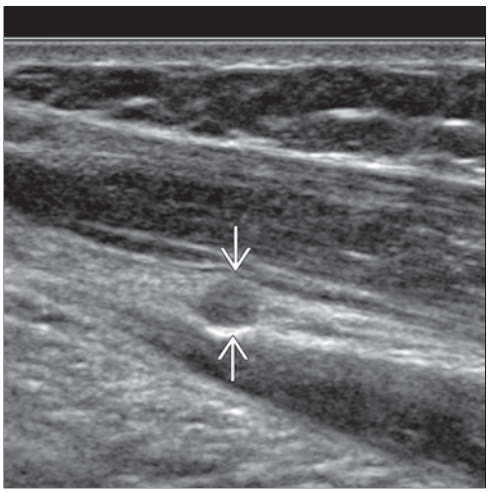


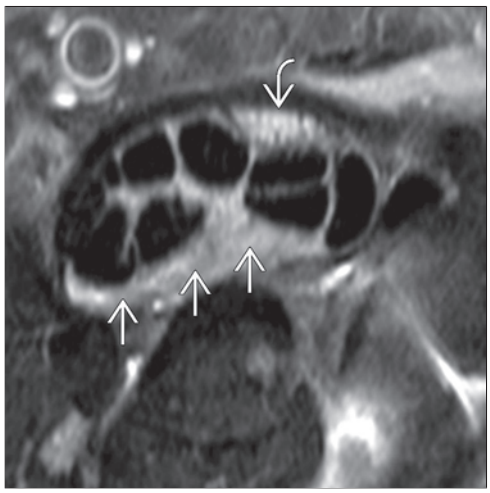


(Left) *Longitudinal ultrasound of the median nerve in the same patient shows that the mass ➔ is ovoid-shaped with a rather homogeneous echogenicity & is overall consistent with an intraneural lipoma.* ***(Right)*** *Transverse PDWI MR at the outlet of the midcarpal tunnel area in the same patient confirms that the mass is of fat signal intensity ➔ and arising from the ulnar aspect of the median nerve ➔. The overall appearances are consistent with a lipoma of the median nerve.*

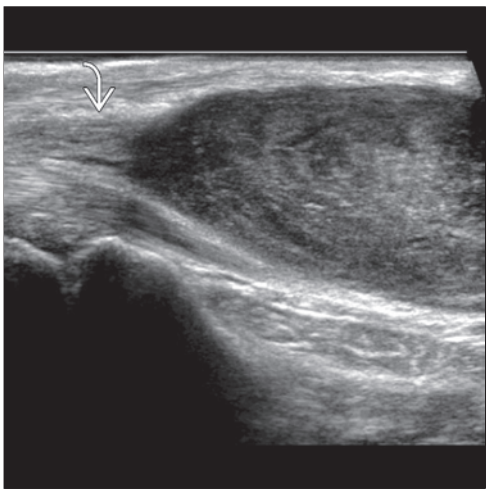


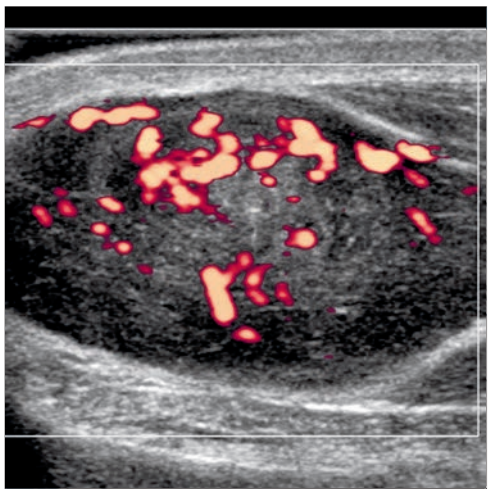




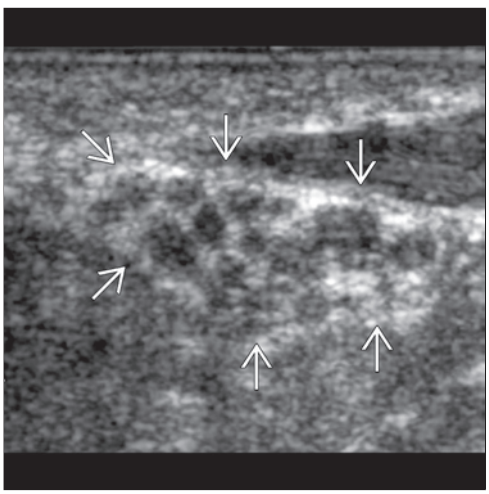


(Left) *Longitudinal US of the median nerve at the distal forearm shows a well-defined hypoechoic round intraneural lesion ➔, consistent with a small nerve sheath tumor. MR (not shown) revealed an enhancing intraneural lesion compatible with neurogenic tumor.* ***(Right)*** *Transverse MR arthrogram PDWI FS in a patient with CTS symptoms shows median nerve flattening ➔ at the tunnel outlet with synovial proliferation of the ulnar flexor synovial sheath ➔, consistent with flexor tenosynovitis.*





(Left) *Longitudinal ultrasound in a patient with CTS symptoms shows a large, heterogeneous, oval-shaped tumor continuous with the median nerve just proximal to the carpal tunnel. The nerve immediately adjacent to the tumor is mildly thickened ➔. Features are compatible with a large median nerve sheath tumor.* ***(Right)*** *Longitudinal power Doppler ultrasound shows moderate tumoral hyperemia with an irregular vascular pattern. This is consistent with a nerve sheath tumor.*





(Left) *Transverse ultrasound in a patient with enlarged middle finger & recent onset of CTS symptoms during pregnancy shows a very thickened median nerve ➔ at the tunnel inlet with thickened hypoechoic intraneural fascicles. These appearances are consistent with hamartomatous fibrolipoma of the median nerve.* ***(Right)*** *Frontal radiograph in the same patient shows middle finger macrodactyly, a known association of median nerve fibrolipoma & a more common presenting symptom than CTS.*

CUBITAL TUNNEL SYNDROME

Key Facts

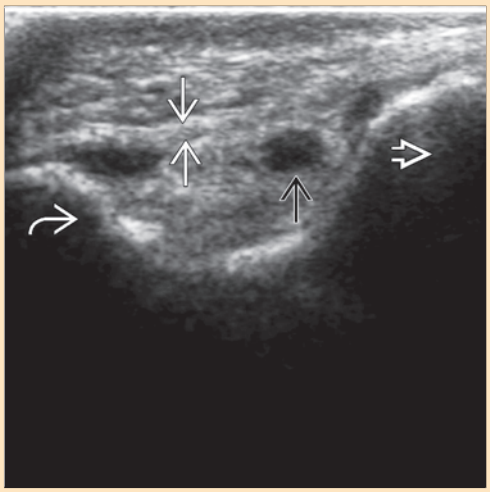
Terminology
- Symptoms secondary to compression of ulnar nerve at cubital tunnel
- 2nd most common peripheral entrapment neuropathy

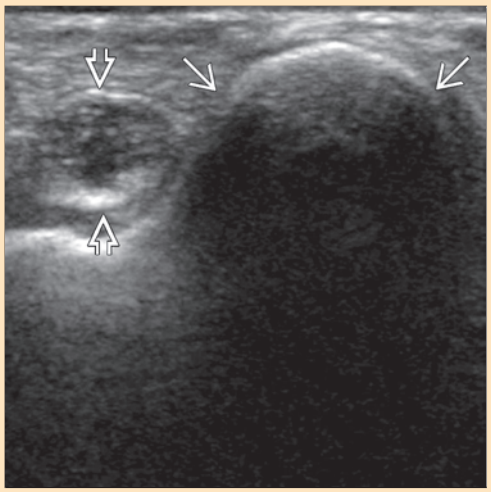
Imaging
- Best diagnostic clue: Swollen ulnar nerve just proximal to or within cubital tunnel
- Ulnar nerve cross-sectional measurements obtained at 4 points: Mid- to distal arm, proximal to tunnel, within tunnel, and distal to tunnel
- 2 criteria used to help establish diagnosis
  - If cross-sectional area of ulnar nerve at cubital tunnel ≥ 10 mm², sensitivity 93%, specificity 98%, positive predictive value 93%, negative predictive value 98%
  - Ulnar nerve cross-sectional area in tunnel should not be > 1.5x cross-sectional area in mid- to distal arm region
- Always check for ulnar nerve subluxation
  - Ulnar nerve subluxation is a risk factor for development of cubital tunnel syndrome
  - 20% of subjects with ulnar nerve subluxation may be asymptomatic
- Look for space occupying masses (ganglia), osteophytes, synovitis, or anconeus epitrochlearis accessory muscle

Pathology
- No specific structural cause found (majority)
- Traction of ulnar nerve with elbow flexion considered major etiological factor

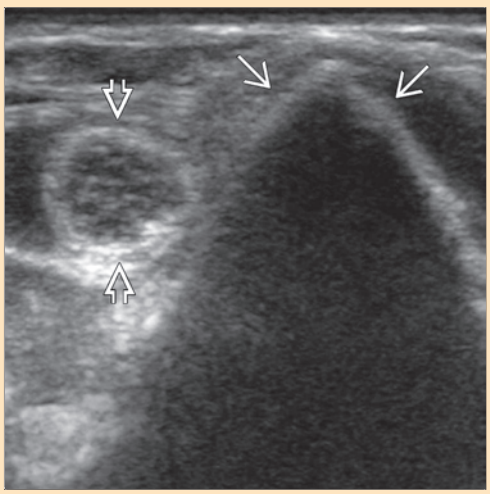
Diagnostic Checklist
- The more swollen the ulnar nerve, the more likely the possibility of cubital tunnel syndrome

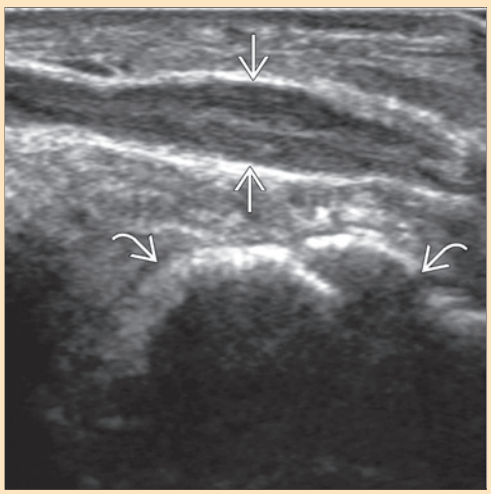
(Left) *Transverse ultrasound shows the normal ulnar nerve within the cubital tunnel, which is bound by the Osborne ligament. Note the medial epicondyle and olecranon.* ***(Right)*** *Transverse ultrasound shows a moderately enlarged (22 mm²) ulnar nerve, located within the cubital tunnel just ulnar to the medial epicondyle. Nerve area ≥ 10 mm² is a positive predictor for cubital tunnel syndrome.*





(Left) *Transverse ultrasound shows a severely enlarged (25 mm²) ulnar nerve located just proximal to the cubital tunnel. Note the distal humerus. Often ulnar enlargement will extend a few mm proximal to the cubital tunnel.* ***(Right)*** *Longitudinal ultrasound shows a focally enlarged ulnar nerve within & just proximal to the cubital tunnel. Note the medial epicondyle. These findings are consistent with cubital tunnel syndrome.*





CUBITAL TUNNEL SYNDROME

TERMINOLOGY

Abbreviations
- Cubital tunnel syndrome (CUTS)

Synonyms
- Elbow entrapment, tardy ulnar nerve palsy, ulnar neuropathy at elbow (UNE)

Definitions
- Symptoms secondary to compression of ulnar nerve at cubital tunnel
  - 2nd most common entrapment neuropathy of peripheral nerve after carpal tunnel syndrome

IMAGING

General Features
- Best diagnostic clue
  - Swollen ulnar nerve just proximal to and within cubital tunnel
- Location
  - Immediately posterior to medial humeral epicondyle
- Size
  - Normal nerve cross-sectional area is from 4-12 mm²
- Morphology
  - Fusiform appearance on longitudinal scanning due to localized swelling

Radiographic Findings
- Radiography
  - Elbow osteoarthrosis with osteophytic impingement into cubital tunnel, especially with hypertrophic osteoarthrosis
  - Also assess for signs of instability, deformity from old trauma, or any encroachment into cubital tunnel

MR Findings
- T1WI
  - Swelling of ulnar nerve
- T2WI
  - Swelling of ulnar nerve
  - Hyperintensity of enlarged ulnar nerve
- DWI
  - May show nerve compression before electrophysiologic abnormality

Ultrasonographic Findings
- Best diagnostic tool in ulnar nerve entrapment
- Swelling of ulnar nerve just proximal to or within cubital tunnel
- Measurements obtained at 4 points: Mid- to distal arm, just proximal to tunnel, within tunnel, and distal to tunnel
  - The more swollen the median nerve, the more likely the possibility of cubital tunnel syndrome
- Cross-sectional area preferred to diameter
- No agreed cut-off point to define abnormally enlarged cross-sectional area of ulnar nerve
  - Rigid criteria are not likely to be useful in clinical practice
    - Known inter- and intraobserver measurement error ± interpopulation variation
  - Most reliable discriminatory measure has yet to be established
    - Combination of several criteria may prove most useful
- Mean ulnar nerve cross-sectional area in healthy subjects is 6.5 mm² at cubital tunnel
- For cut-off of 8.3 mm² cross-sectional area of ulnar nerve at cubital tunnel: Sensitivity 100%, specificity 93%
- For cut-off of 10 mm² cross-sectional area of ulnar nerve at cubital tunnel: Sensitivity 93%, specificity 98%, positive predictive value 93%, negative predictive value 98%
- May occasionally show abrupt narrowing or displacement of nerve within tunnel
- Look for space occupying masses (ganglia), osteophytes, synovitis, or anconeus epitrochlearis accessory muscle
  - Anconeus epitrochlearis accessory muscle in 11% of normal subjects, bilateral in 25%
  - Runs over cubital tunnel between medial epicondyle and olecranon

Imaging Recommendations
- Best imaging tool
  - Ultrasound: Quick, comfortable, cost effective, accurate, and dynamic
- Protocol advice
  - Can use 1 of 4 positions
    - Position 1: Supine position with arm abducted
    - Position 2: Prone position with arms placed near body in slight flexion and arm pronated to turn palmar face of hand upward
    - Position 3: Sitting sideways opposite operator with arm abducted
    - Position 4: Sitting facing operator with arm and forearm externally rotated
  - Identity nerve in distal arm in transverse plane
    - In transverse plane, trace course of nerve distally to elbow
  - Maximum caliber of ulnar nerve criterion
    - Measure cross-sectional area of nerve by tracing outer boundary of nerve with electronic calipers
      - Measure nerve caliber at mid- to distal arm, just proximal to tunnel, within tunnel, and just distal to tunnel
  - Swelling ratio criterion
  - Convenient but may not be more accurate than maximum cross-sectional area
    - Compare cross-sectional area of nerve within tunnel with that in mid-distal arm
    - Cross-sectional area within cubital tunnel should not be > 1.5x than that in mid- to distal arm
  - May get diffuse nerve enlargement in diabetes, alcoholism, amyloidosis, morbid obesity, or Charcot-Marie-Tooth disease
  - Always check for ulnar nerve subluxation
    - Risk factor for development of cubital tunnel syndrome
    - 20% of subjects with ulnar nerve subluxation may be asymptomatic
  - General tips
    - Try to keep transducer aligned at right angles and not oblique to nerve
    - Still, slight angulation of transducer can utilize anisotropy to improve nerve delineation

CUBITAL TUNNEL SYNDROME

- Best to make measurements immediately after freezing image
- Measure cross-sectional area of nerve by trace rather than with ellipsoid calipers

DIFFERENTIAL DIAGNOSIS

Ulnar Nerve Compression
- Proximal to cubital tunnel: Arcade of Struthers, medial intermuscular septum
- Distal to cubital tunnel: Deep to flexor pronator aponeurosis, between ulnar and humeral heads of flexor carpi ulnaris (FCU)

Nerve Sheath Tumor
- Localized mass-like nerve swelling

Common Flexor Tendon Origin Tendinosis With Peritendinitis
- May irritate ulnar nerve in cubital tunnel

PATHOLOGY

General Features
- Most likely results from ischemia or compression of ulnar nerve within cubital tunnel
- Course of ulnar nerve
  - Starts as terminal branch of medial cord of brachial plexus
  - Continues between medial head of triceps brachii and brachialis muscles
  - Lies posteromedial to brachial artery, just posterior to intermuscular septum
  - Crossed by arcade of Struthers (fascia between medial head of triceps and intermuscular septum) ~ 3.5 cm proximal to medial epicondyle
  - Then courses posterior to medial epicondyle, medial to olecranon, and enters cubital tunnel
  - Passes deep to flexor pronator aponeurosis and then deep into forearm between ulnar and humeral heads of flexor carpi ulnaris (FCU) muscle
- Anatomy of cubital tunnel
  - Roof: Osborne fascia (thickened transverse fascial band between medial epicondyle and olecranon)
  - Floor: Medial collateral ligament of elbow, elbow joint capsule, and olecranon
  - More distally: Another tunnel formed by humeral and ulnar heads of FCU bridged by arcuate ligament
- Etiology
  - No specific structural cause found (majority)
  - Traction of ulnar nerve with elbow flexion is major contributor
  - CUTS increased in
    - Recurrent subluxation of ulnar nerve, old trauma, heavy lifting, weightlifting, habitual positioning of elbow on hard surface, repetitive elbow flexion, diabetes, thyroid disease, hemophilia, and peripheral neuropathy
- Epidemiology
  - Incidence ~ 1% in United States

Gross Pathologic & Surgical Features
- Compressed nerve in cubital tunnel

Microscopic Features
- Nerve compression or ischemia leads to fluid leakage/endoneural edema and increase in endoneural pressure
  - Leads to demyelination, inflammation, damming of axoplasmic flow, distal axonal degeneration, fibrosis, growth of new axons, remyelination, and thickening of perineurium and epineurium

CLINICAL ISSUES

Presentation
- Most common signs/symptoms
  - Paraesthesia and numbness of ulnar 1 and 1/2 digits, but frequently difficult to localize
- Other signs/symptoms
  - Pain medial elbow region
  - Grip problems secondary to intrinsic muscle (lumbrical and interosseous) weakness and atrophy
  - Claw hand: Hyperextension of proximal phalanx with flexion of middle and distal phalanges
- Clinical profile
  - Ultrasound findings supported by combination of history, physical examination, specific provocative tests, and electrophysiologic tests
  - Provocative tests
    - Positive Tinel test, elbow flexion test, pressure provocation test, combined elbow flexion-pressure test, scratch collapse test
  - Electrodiagnostic studies (EDS) test functional integrity of nerve
    - Ulnar nerve motor conduction velocity (MCV) across elbow positive if < 50 m/s
    - Can identify other disease processes such as upper motor neuron disease or peripheral neuropathy

Demographics
- Age
  - Peak: 55 ± 12.5 years
- Gender
  - M:F = 1:3

Treatment
- Conservative
  - Anti-inflammatory or vitamin B medication, elbow pad activity modification, splints to limit motion, nocturnal splinting, physical therapy
- Surgical
  - In situ decompression, subcutaneous/intramuscular/submuscular transposition, medial epicondylectomy

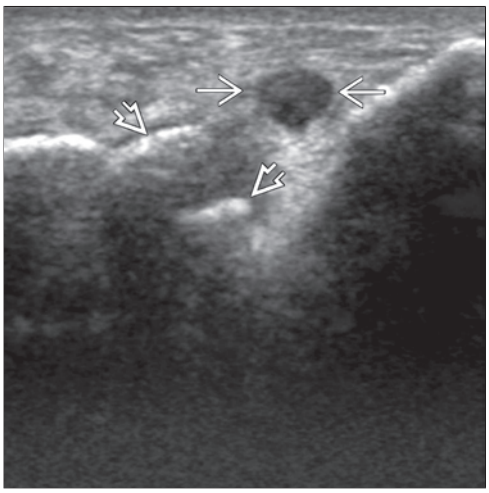
DIAGNOSTIC CHECKLIST

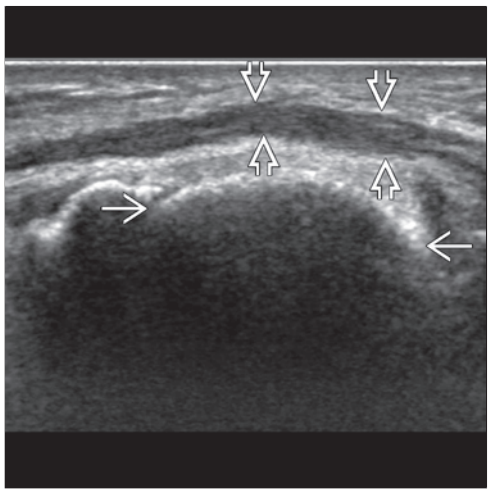
Consider
- CUTS in all patients with unexplained hand, wrist, or distal forearm paresthesia ± pain on ulnar side

Image Interpretation Pearls
- The more swollen the ulnar nerve, the more likely the possibility of cubital tunnel syndrome

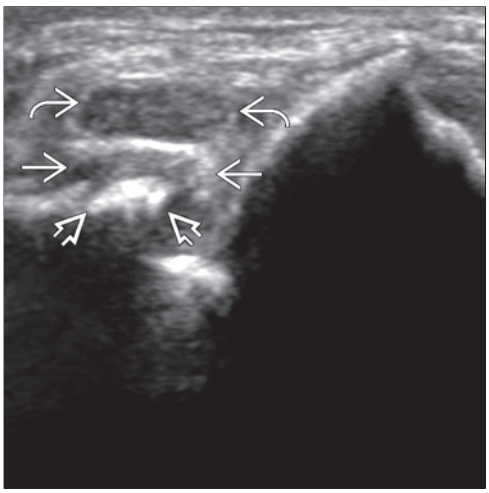
SELECTED REFERENCES

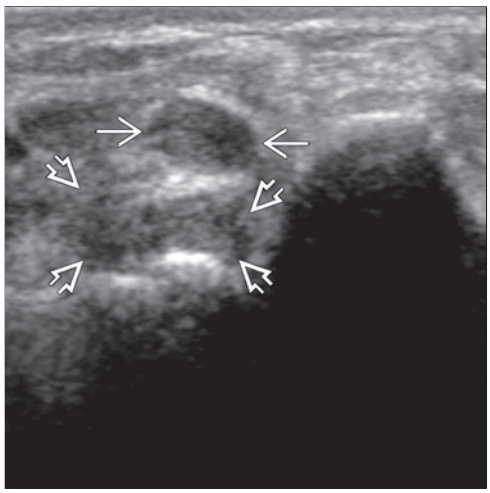
1. Palmer BA et al: Cubital tunnel syndrome. J Hand Surg Am. 35(1):153-63, 2010



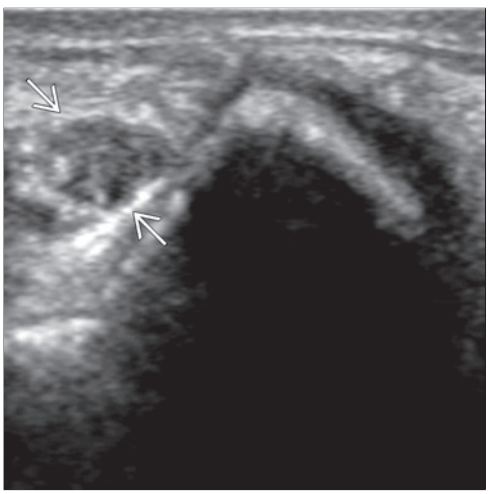


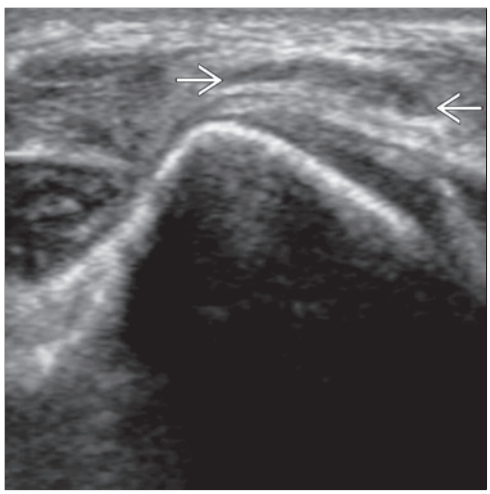
(Left) *Transverse ultrasound shows mild enlargement (15 mm²) of the ulnar nerve. Osteophytes indenting the cubital tunnel predispose to development of cubital tunnel syndrome.* ***(Right)*** *Longitudinal ultrasound of the same patent shows mild diffuse enlargement of the ulnar nerve in the cubital tunnel. Note the medial epicondyle.*





(Left) *Transverse ultrasound shows moderate enlargement (20 mm²) of the ulnar nerve, consistent with cubital tunnel syndrome. Osteophyte associated with a thin layer of hypoechoic synovial thickening impinges onto the ulnar nerve.* ***(Right)*** *Transverse ultrasound shows mild to moderate enlargement (17 mm²) of the ulnar nerve within the cubital tunnel. Anechoic paraarticular ganglion displaces the ulnar nerve.*





(Left) *Transverse ultrasound shows moderate enlargement (16 mm²) of the ulnar nerve within the cubital tunnel in the extended elbow position. These features are compatible with cubital tunnel syndrome.* ***(Right)*** *Transverse ultrasound of the same patient with full elbow flexion shows dislocation of the ulnar nerve, which is now flattened. Ulnar nerve subluxation is a risk factor for development of cubital tunnel syndrome.*

TARSAL TUNNEL SYNDROME

Key Facts

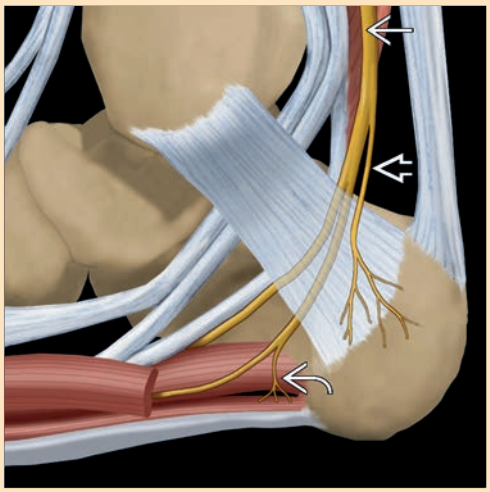
Terminology

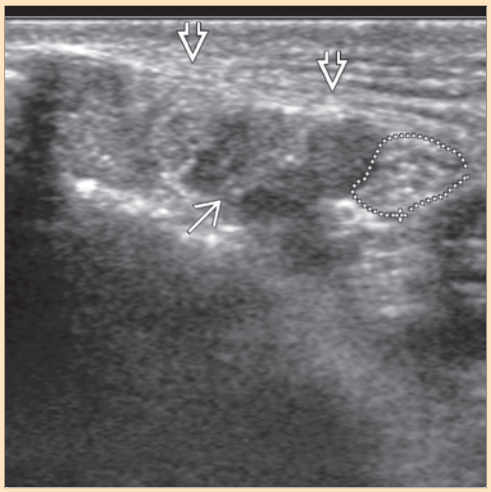
- Neuropathy of tibial nerve and its branches (medial and lateral plantar nerves) on medial aspect of ankle
  - Many causes of tarsal tunnel syndrome
- 2 forms of tarsal tunnel syndrome
  - Upper: Compression within tarsal tunnel (classic)
  - Lower: Compression deep and distal to abductor hallucis fascia (variant)
- Tarsal tunnel syndrome is much less common than carpal or cubital tunnel syndromes

Imaging

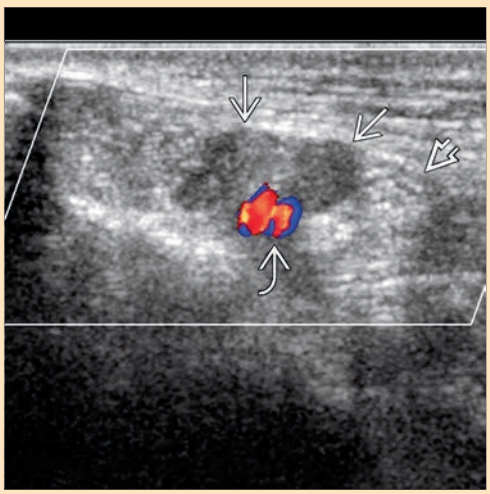
- Mass within tarsal tunnel (ganglion, lipoma, tendon disorder with peritendinitis, venous engorgement)
  - Most useful diagnostic imaging feature
- Extrinsic mass encroaching upon tarsal tunnel (synovial proliferation, bony overgrowth)
- Intrinsic nerve abnormality (fibrosis, tumor, diffuse enlargement)
- Altered tibial nerve caliber (enlarged proximally, narrowed at site of compression)
  - Ultrasound diagnostic criteria for tarsal tunnel syndrome are not established
  - Normal CSA of tibial nerve in tibial tunnel = 11.7 ± 4.8 mm² (measurements not validated)
  - Side-to-side tibial nerve CSA measurement (> 1.8 mm² is abnormal) may be more useful than absolute measurements
- Nerve conduction studies are of limited use
- MR is helpful for additional investigation
  - Also useful in determining and grading hindfoot muscle atrophy (nonspecific sign)
  - 8% of asymptomatic subjects have moderate abductor digiti minimi atrophy, whereas 1-3% have moderate atrophy of other hindfoot muscles

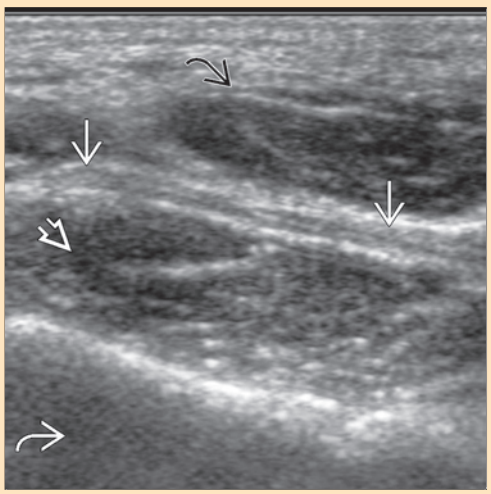
(Left) *Schematic shows the tarsal tunnel with the tibial nerve dividing into the medial and lateral plantar nerves under the flexor retinaculum. The medial calcaneal nerve normally comes off the tibial nerve proximal to the retinaculum. The inferior calcaneal nerve is the 1st branch of the lateral plantar nerve.* ***(Right)*** *Transverse ultrasound of the upper tarsal tunnel shows the tibial nerve (outlined) alongside the neurovascular bundle deep to the flexor retinaculum. This nerve measures 14.9 mm².*





(Left) *Transverse color Doppler ultrasound in normal subject shows the posterior tibial artery alongside the tibial nerve. The paired posterior tibial veins do not demonstrate color flow.* ***(Right)*** *Longitudinal ultrasound of the lower tibial tunnel shows the lateral plantar nerve extending between the adductor hallucis and quadratus plantae muscles. This is a site where the lateral plantar nerve can become trapped. The calcaneum is normal.*





TARSAL TUNNEL SYNDROME

TERMINOLOGY

Definitions

- Neuropathy of tibial nerve and its branches on medial aspect of ankle
  - 2 forms of tarsal tunnel syndrome
    - Upper: Compression of tibial nerve within tarsal tunnel (classic)
      - Upper tarsal tunnel extends from retromalleolar region to proximal end of abductor hallucis muscle
    - Lower: Compression of plantar nerves in their separate tunnels deep and distal to abductor hallucis fascia (variant)
      - Lower tarsal tunnel lies distal to abductor hallucis muscle

IMAGING

General Features

- Location
  - Tarsal tunnel is posteroinferior to medial malleolus
    - Roof: Flexor retinaculum (laciniate ligament) and abductor hallucis muscle
    - Floor: Calcaneum, talus, posterior talocalcaneal articulation, deltoid ligament, distal tibia
    - Contents: "**T**om, **D**ick, **A**nd a **V**ery **N**ervous **H**arry" (**t**ibialis posterior, flexor **d**igitorum longus, posterior tibial **a**rtery, posterior tibial **v**eins, tibial **n**erve, flexor **h**allucis longus)
  - Tibial nerve passes deep to flexor retinaculum and divides into medial and lateral plantar branches
    - In 5% of subjects, tibial nerve divides into its terminal branches before it enters tarsal tunnel
  - Flexor retinaculum at tarsal tunnel is less taut and more distensible than that of carpal tunnel
    - Becomes less distensible when thickened and fibrosed
  - Medial plantar nerve innervates abductor hallucis, flexor digitorum brevis, flexor hallucis brevis, and 1st lumbrical muscle
    - Runs approximately from anteromedial aspect of calcaneum along the medial aspect of the foot (along line of flexor hallucis longus tendon)
    - Provides sensation to medial part of sole of foot and medial 3 toes
  - Lateral planar nerve
    - First descends steeply between abductor hallucis and quadratus plantae, then runs anterolaterally on surface of quadratus plantae muscle
    - Runs approximately from anteromedial aspect of calcaneum to base of little toe
    - Provides sensation to lateral part of sole of foot and lateral 3 toes
    - Innervates remaining deep foot muscles (including the hindfoot muscles most closely applied to calcaneum, i.e., quadratus plantae and abductor digiti minimi)
  - Inferior calcaneal nerve (Baxter nerve) is 1st branch of lateral plantar nerve
    - It arises at lower end of abductor hallucis/quadratus plantae interspace before lateral plantar nerve turns anteriorly
      - Then runs between quadratus plantae and flexor digitorum brevis
      - Then passes anterior to medial calcaneal tuberosity to pierce and innervate digiti minimi muscle
    - Mixed motor and sensory nerve
      - Motor innervation supplies abductor digiti minimi, occasionally flexor digitorum brevis and lateral 1/2 of quadratus plantae muscle
      - Sensory to calcaneal periosteum, long plantar ligament, and adjacent vessels
      - Because of its course and sensory innervation, symptoms of either Baxter nerve impingement or neuritis can be indistinguishable from plantar fasciitis
    - Compression leads to denervation edema or atrophy of abductor digiti minimi ± other muscles
      - However, adductor digiti minimi atrophy (≥ moderate severity) can be seen in ~ 8% of otherwise normal subjects
      - Flexor digitorum brevis, quadratus plantae, and abductor digiti minimi atrophy (≥ moderate) found in 1-3% of otherwise normal subjects
      - Therefore, clinical significance of hindfoot muscle atrophy is not clear

MR Findings

- T1W1 or PD
  - Yields high-resolution, high-contrast images of tarsal tunnel nerves
  - Axial images are most useful for nerve anatomy, branching variations, assessing perineural fibrosis, and space-occupying lesions
    - Also assess for atrophic fatty atopy of foot muscles and grade as mild (< 25%), moderate (26-50%), severe (51-75%), or very severe (> 76%)
    - Especially assess 4 main hindfoot muscles (abductor hallucis, flexor digitorum brevis, quadratus plantae, abductor digiti minimi)
  - Coronal images are most useful for assessing osseous or synovial encroachment onto tarsal tunnel
- T2WI FS
  - Best for detection of nerve hyperintensity, ganglia, soft tissue edema, and muscle edema
  - Nerve swelling, hyperintensity, and loss of fascicular pattern tend to occur proximal to and at site of nerve compression

Ultrasonographic Findings

- Mass lesion within tarsal tunnel
  - Ganglion, lipoma, synovial proliferation, tendon disorder with peritendinitis, venous engorgement
- Change in tibial nerve caliber (enlarged proximally, narrowed at site of compression)
  - Ultrasound diagnostic criteria for tarsal tunnel syndrome are not established

Imaging Recommendations

- Best imaging tool
  - Ultrasound, since tibial nerve can be consistently seen as well as compression or abnormality of tibial nerve
    - No established diagnostic ultrasound criteria for tarsal tunnel syndrome, unlike carpal tunnel or cubital tunnel syndrome

TARSAL TUNNEL SYNDROME

        - Tarsal tunnel syndrome is much less common than carpal or cubital tunnel syndromes
    - MR is helpful if signs/symptoms are not fully explained by ultrasound examination
        - Particularly helpful in assessing abnormality of distal part of lower tarsal tunnel since thick plantar skin can hinder ultrasound examination
    - Nerve conduction studies show absent medial and lateral plantar sensory nerve action potentials (SNAPs)
        - May also show prolonged medial and lateral plantar motor latencies
        - Not specific for tarsal tunnel syndrome as can be seen in sensory polyneuropathy or in elderly patients
        - Overall, nerve conduction studies in tarsal tunnel syndrome are of limited value
- Protocol advice
    - Patient lies supine with hip abducted or in a decubitus position with medial ankle facing upward
    - Scan transversely over tarsal tunnel (malleolar calcaneal axis) keeping tibial nerve in cross section
    - Check especially for
        - Mass present within tarsal tunnel (lipoma, ganglion, tendon abnormality, venous congestion)
        - Mass encroaching onto tarsal tunnel (synovial proliferation, bony overgrowth)
        - Intrinsic abnormality of tibial nerve (fibrosis, tumor, diffuse enlargement)
    - Check for change in caliber of tibial nerve
    - For retromalleolar measurements with ankle in neutral position
        - Normal cross-sectional area (CSA) of tibial nerve in tibial tunnel reported as 11.7 ± 4.8 mm² (measurements are not validated by other studies)
        - Side-to-side difference in tibial nerve CSA > 1.8 mm² is considered abnormal
            - Therefore, side-to-side comparison in patients with unilateral tarsal tunnel syndrome may be more accurate than absolute measurement
        - Normal flexor retinaculum thickness = 0.64 ± 0.03 mm
        - Normal depth of tarsal tunnel = 11.9 ± 0.9 mm
    - Patients with tarsal tunnel syndrome tend to have smaller tibial nerve CSA within tunnel and thicker flexor retinacula than normal subjects
    - Check for atrophy of small hindfoot muscles

DIFFERENTIAL DIAGNOSIS

Posterior Tibial Disorders

- Thickening, hypoechogenicity, with loss of normal fibrillar pattern of posterior tibialis tendon
    - Many have tendon tears (splits) ± variable degree of peritendinitis
        - May lead to tarsal tunnel syndrome

Tarsal Coalition

- Hypertrophic bone protruding from midtalocalcaneal articulation is a good ultrasound sign of subtalar coalition

Plantar Fasciitis

- Thickening (> 4 mm) of plantar fascia at leading edge of medial calcaneal tuberosity
    - ± perifascial edema or plantar calcaneal spur
- Identical symptoms to inferior calcaneal neuropathy (neuritis or compression) (Baxter neuritis)

CLINICAL ISSUES

Presentation

- Most common signs/symptoms
    - Pain in region of medial malleolus radiating to medial aspect of foot
        - If symptoms are confined to 1 of the plantar nerves, distal tarsal tunnel compression may be implicated
- Other signs/symptoms
    - Paraesthesia or burning sensation in plantar aspect of foot ± hyperesthesia on medial aspect of sole
        - Sparing of heel region, which is innervated by medial calcaneal nerve
    - Weakness ± atrophy of foot muscles
        - Weakness is usually asymptomatic as function is not affected
    - Tenderness behind medial malleolus ± Tinel sign
    - Induction of symptoms by passive dorsiflexion and eversion of ankle for 10 seconds

Demographics

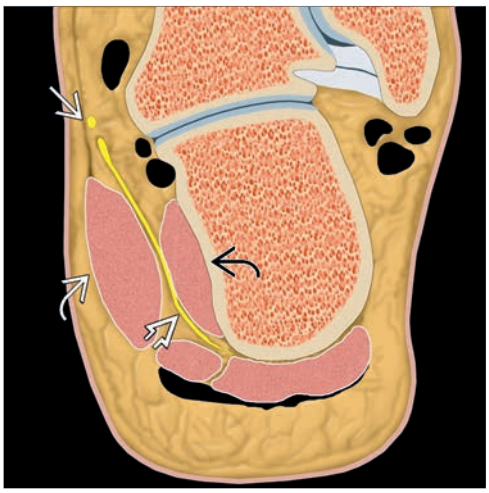
- Age
    - Typically young or middle-aged patient
- Gender
    - Male:female = 2:1
- Epidemiology
    - Many causes of tarsal tunnel have seen described
        - Mass within tarsal tunnel (ganglion, lipoma, nerve sheath tumor, synovial proliferation, tendon enlargement, venous engorgement)
        - Deformity with heel valgus or varus
        - Accessory muscles
            - Accessory flexor digitorum longus muscle (originates medial aspect distal tibia and inserts into quadratus plantae)
            - Peroneus calcaneus internae (originates distal fibula and inserts medial aspect calcaneum)
        - Osseous prominences from ankle or hindfoot arthropathy, talocalcaneal coalition, or calcaneal fracture
        - Post-traumatic perineural fibrosis
        - Intrinsic nerve abnormality (chronic inflammatory demyelinating polyneuropathy with nerve swelling, nerve sheath tumor)
        - Hypertrophic flexor retinaculum
        - Still no cause found in 20% of patients with tarsal tunnel syndrome

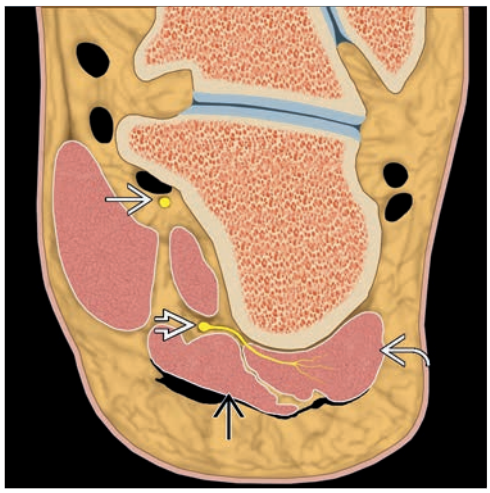
Treatment

- Conservative treatment
- Surgical division (open or endoscopic) of flexor retinaculum ± abductor hallucis muscle fasciotomy
    - Leads to symptomatic improvement in 50% of patients

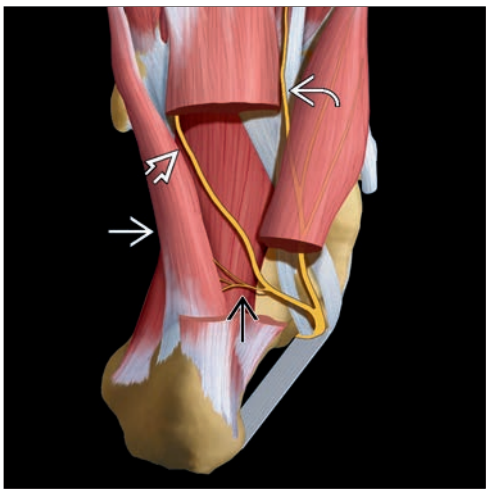
SELECTED REFERENCES

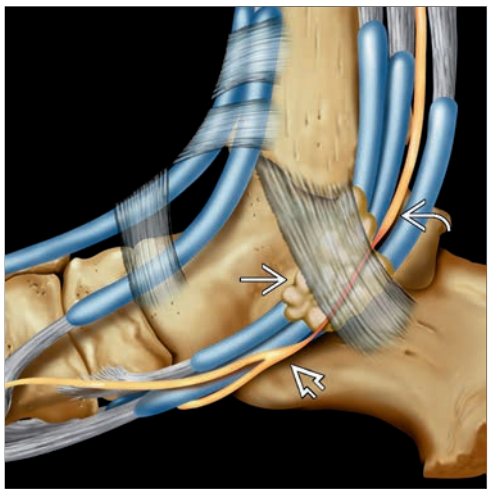
1. Ng JM et al: US and MR imaging of the extensor compartment of the ankle. Radiographics. 33(7):2047-64, 2013





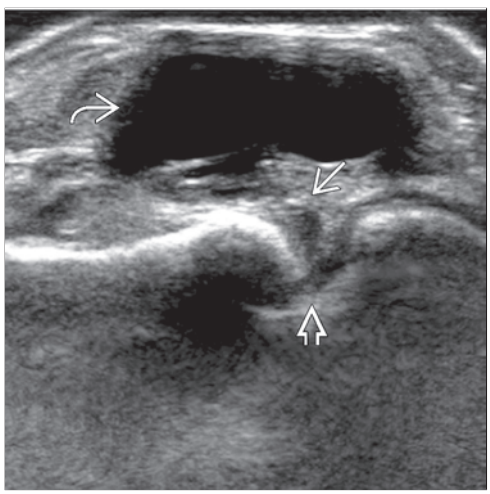
(Left) *Schematic shows the medial and lateral plantar nerves in the proximal portion of the lower tarsal tunnel. Note how the lateral plantar nerve dips inferiorly between the abductor hallucis and quadratus plantae muscles.* ***(Right)*** *Schematic of the distal portion of the lower tarsal tunnel shows the medial and lateral plantar nerves. Note how the lateral plantar nerve extends deep to the flexor digitorum brevis before supplying the abductor digiti minimi muscle.*





(Left) *Schematic of the undersurface of the hindfoot shows how the inferior calcaneal nerve passes laterally on the deep surface of the calcaneum to supply the abductor digiti minimi. The medial and lateral plantar nerves extend to the medial and lateral aspects of the forefoot, respectively.* ***(Right)*** *Schematic shows a ganglion compressing the tibial nerve within the tarsal tunnel. In this schematic, the tibial nerve divides distal to the upper tarsal tunnel, which is a less common anatomical variant.*

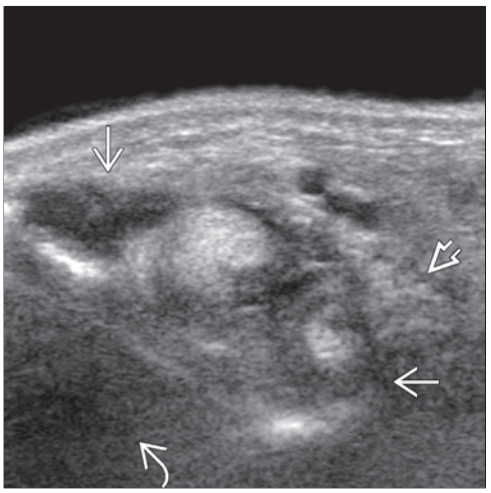


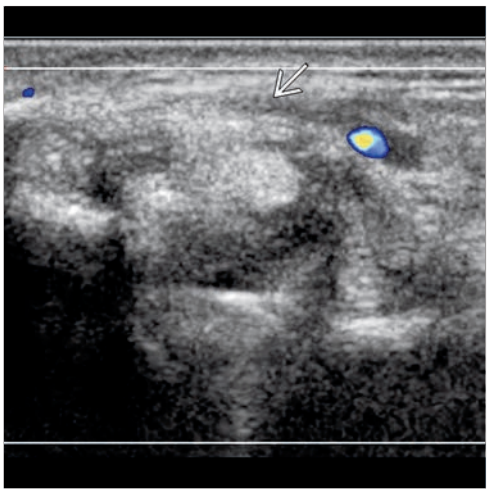


(Left) *Axial PDWI MR in a patient with tarsal tunnel syndrome shows a medium-sized ganglion cyst located between and compressing the medial and lateral plantar nerves within the tarsal tunnel.* ***(Right)*** *Longitudinal ultrasound in a patient with medial foot pain shows a ganglion alongside and arising from the metatarsophalangeal joint. This was the likely cause of pain with no symptoms of tarsal tunnel syndrome in this patient. The irregular stalk connecting the ganglion to the joint is visible.*

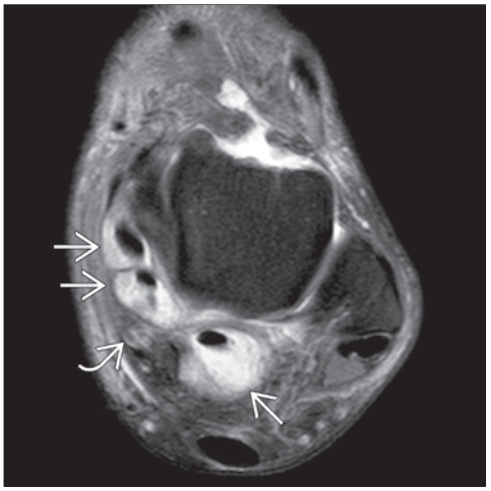
TARSAL TUNNEL SYNDROME

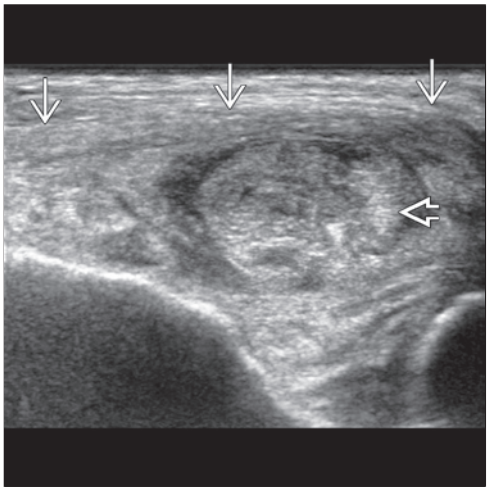
(Left) *Transverse ultrasound in a patient with tarsal tunnel syndrome shows marked synovial proliferation* ➔ *from the posterior talocalcaneal articulation and ankle joint bulging into the tarsal tunnel with compression of the tibial nerve* ➔. *The calcaneum* ➔ *is normal.* ***(Right)*** *Transverse color Doppler ultrasound shows no demonstrable hyperemia of this synovial proliferation* ➔.





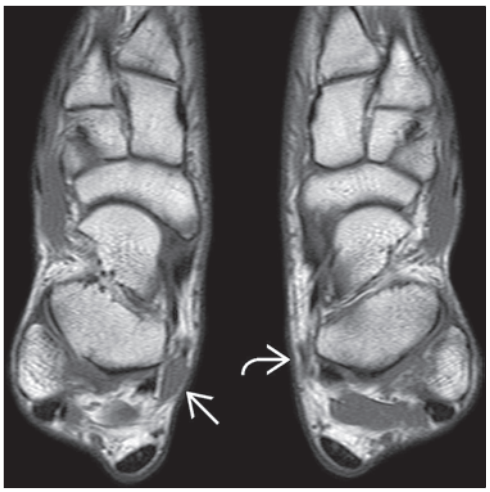
(Left) *Axial T2WI FS MR in a patient with tarsal tunnel syndrome shows tendon sheath effusions of the medial ankle tendons* ➔ *and hyperintensity of the tibial nerve* ➔ *within the tarsal tunnel.* ***(Right)*** *Transverse ultrasound in a patient with tarsal tunnel syndrome shows severe posterior tibialis tendinosis* ➔ *with moderate peritendinitis and thickening of the flexor retinaculum* ➔. *This swelling and edema can lead to tibial nerve compression within the upper tarsal tunnel.*

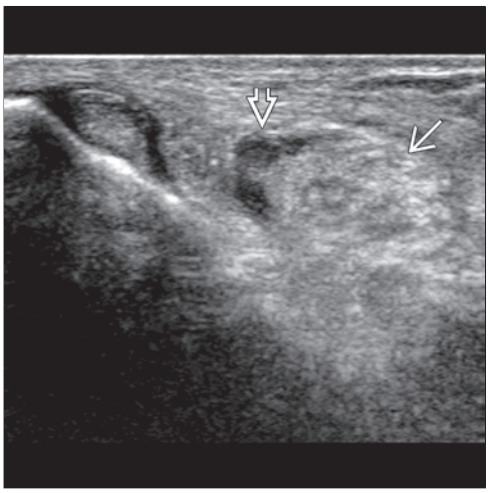


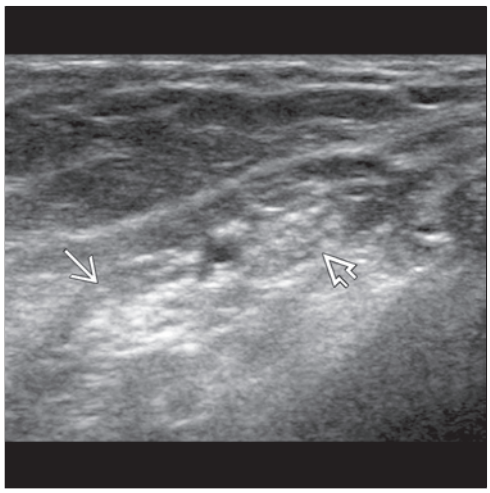


(Left) *Coronal CT reconstruction shows hyperostosis* ➔ *of the narrowed middle talocalcaneal facet in a patient with fibrous-type talocalcaneal coalition. This hyperostosis can impinge onto the tarsal tunnel, giving rise to tarsal tunnel syndrome.* ***(Right)*** *Axial T1WI MR shows the accessory flexor digitorum muscle* ➔, *which can extend into the tarsal tunnel and contribute to compression of the tibial nerve. This is a similar, though smaller, accessory muscle* ➔ *on the contralateral side.*

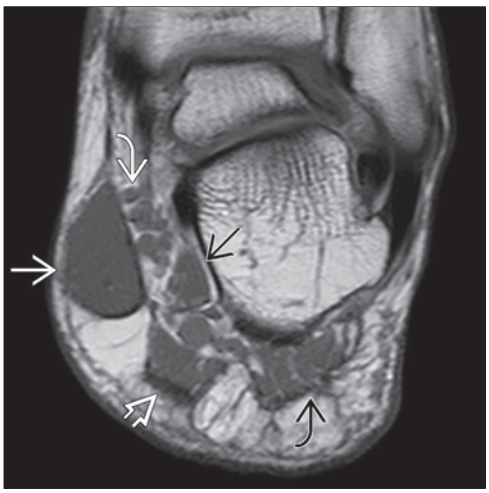


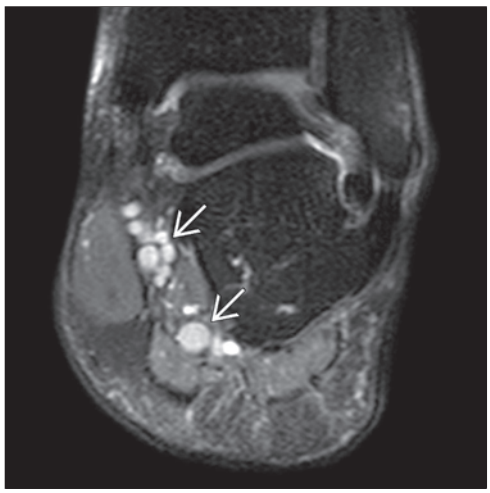




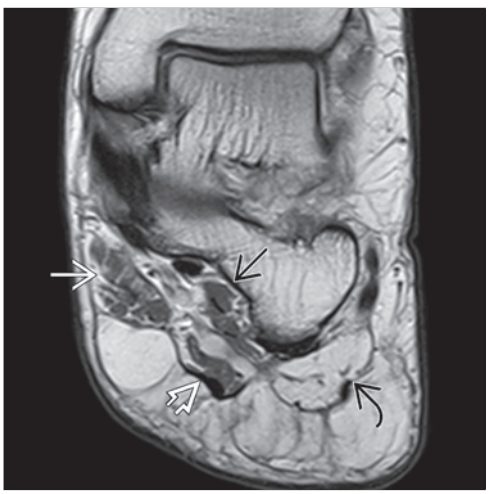


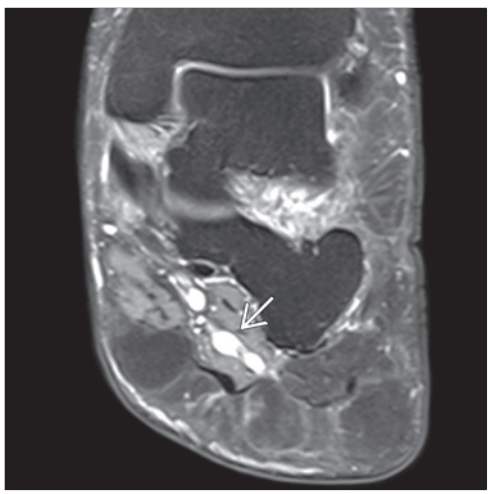
(Left) *Transverse ultrasound in a patient with symptoms of tarsal tunnel syndrome and clinically suspected chronic inflammatory demyelinating neuropathy shows an enlarged tibial nerve within the tarsal tunnel. The nerve cross-sectional area was 34 mm².* ***(Right)*** *Transverse ultrasound in a patient with tarsal tunnel syndrome shows surgically confirmed diffuse lipomatosis of the tarsal tunnel, though no discrete lipoma. The tibial nerve is normal.*





(Left) *Coronal T1WI MR in a patient with tarsal tunnel syndrome shows mild quadratus plantae and abductor digiti minimi atrophy with venous dilatation of the lower tarsal tunnel. The abductor hallucis and flexor digitorum muscles are normal. This pattern is consistent with compression of the lateral plantar nerve.* ***(Right)*** *Coronal T2WI FS MR (same patient) shows venous dilation of the lower tarsal tunnel, which can cause compression of the lateral plantar nerve.*





(Left) *Coronal T1WI MR shows moderate abductor hallucis, flexor digitorum brevis, and quadratus plantae atrophy with severe abductor digiti minimi atrophy, consistent with tarsal tunnel syndrome, particularly affecting the inferior calcaneal nerve (Baxter nerve). (Courtesy K. A. Al-Ismail, MD.)* ***(Right)*** *Coronal T2WI FS MR (same patient) shows mild venous dilatation of the lower tarsal tunnel. (Courtesy K. A. Al-Ismail, MD.)*

VASCULAR DILATATION OR INFLAMMATION

Key Facts

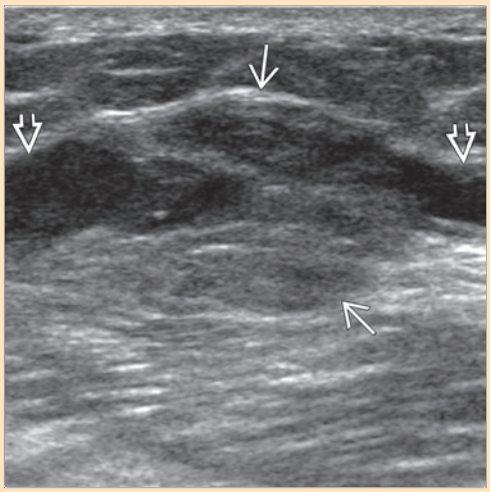
Imaging

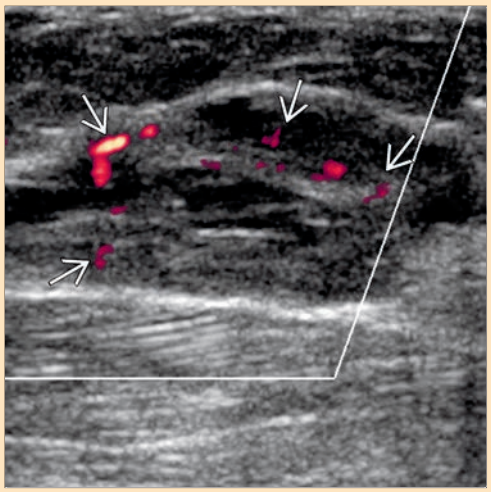
- **Intravascular papillary endothelial hyperplasia**
- Focal vascular dilatation with well-defined intraluminal mass
  - Hypoechoic compared with subcutaneous fat
  - ± hyperechoic septa
  - Color Doppler imaging: Central flow for larger lesions; absent flow for smaller lesions
- **Superficial thrombophlebitis**
- Thrombosed vein surrounded by halo of hyperechoic edematous subcutaneous fat
  - ± perivascular hyperemia
- **Venous varix**
- Focal dilatation of vein
- **Intravascular organized hematoma**
- Focal hypoechoic to hyperechoic lesion within lumen (i.e., hematoma-like lesion within vein)
  - No flow on color Doppler imaging
- **Pseudoaneurysm**
- Hypoechoic or anechoic perivascular mass
  - Neck connects pseudoaneurysm lumen to artery
  - Characteristic "to and fro" flow pattern at neck of pseudoaneurysm
  - Characteristic "yin-yang" sign within pseudoaneurysm sac
  - Thrombus or slow flow within pseudoaneurysm sac is also occasionally seen
- **Kimura disease**
- Fusiform-shaped hypoechoic tumor of arterial wall
  - Variable intratumoral hyperemia on color Doppler imaging

Diagnostic Checklist

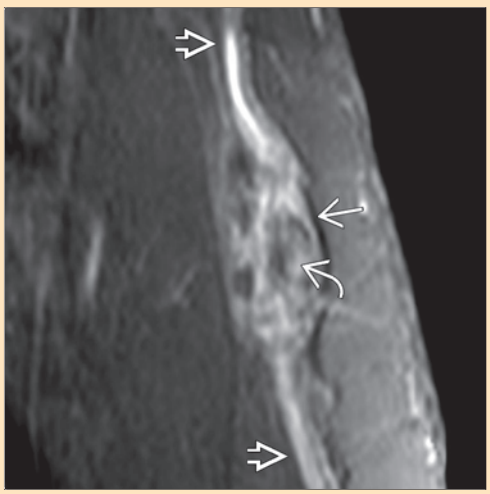
- Ultrasound is best imaging modality for all focal vascular abnormalities, provided vessel can be assessed by ultrasound

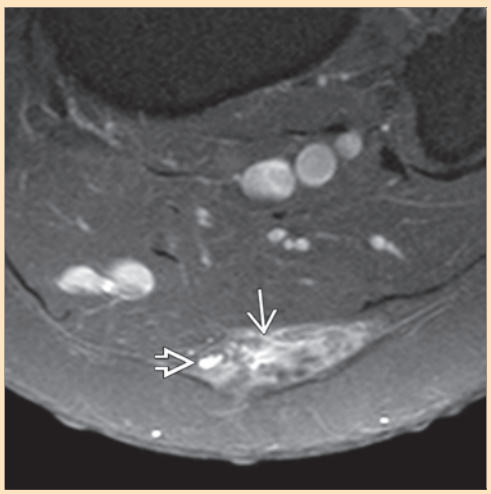
(Left) *Longitudinal ultrasound shows focal dilatation of the short saphenous vein in the popliteal fossa. There is a mildly hypoechoic mass within and around the dilated vein.* ***(Right)*** *Longitudinal color Doppler ultrasound of the same patient shows mild internal vascularity within the mass. These appearances are consistent with intravascular papillary endothelial hyperplasia.*





(Left) *Sagittal T1WI C+ FS MR of the same patient as previous image shows focal dilatation of the short saphenous vein. The vascular and perivascular tumor component shows heterogeneous contrast enhancement. Excision biopsy revealed Masson tumor (intravascular papillary endothelial hyperplasia).* ***(Right)*** *Axial T1WI C+ FS MR of the same patient shows heterogeneous tumor enhancement. The mass arises eccentrically from the short saphenous vein.*





VASCULAR DILATATION OR INFLAMMATION

TERMINOLOGY

Synonyms

- **Intravascular papillary endothelial hyperplasia**: Masson tumor, Masson pseudoangiosarcoma, intravascular angiomatosis, vegetant intravascular hemangioendothelioma
- **Pseudoaneurysm**: False aneurysm

Definitions

- **Intravascular papillary endothelial hyperplasia**
  - Organizing thrombus with excessive reactive papillary endothelial proliferation
- **Superficial thrombophlebitis**
  - Inflammation of superficial vein
- **Venous varix**
  - Focal dilatation of vein
- **Intravascular organized hematoma**
  - Organized hematoma within vessel, usually vein
- **Pseudoaneurysm**
  - Luminal outpouching of artery with
    - Defect in tunica intima and media, and preservation of tunica adventitia
    - Or full thickness wall defect with bleeding contained by hematoma and surrounding soft tissues
- **Kimura disease**
  - Inflammatory response associated with self-limiting allergic or autoimmune reaction to unknown stimulus

IMAGING

General Features

- Location
  - **Intravascular papillary endothelial hyperplasia**
    - Most commonly within vein; rarely within artery
    - Predilection for subcutaneous tissues, extremities, and chest wall
  - **Superficial thrombophlebitis**
    - Superficial venous system, particularly in lower limbs
  - **Venous varix**
    - Most commonly in superficial vein
  - **Intravascular organized hematoma**
    - Any vessel, most commonly within vein
  - **Pseudoaneurysm**
    - Most commonly affects common femoral artery related to needle puncture for angiography
      - Arises from punctured superficial wall of artery
  - **Kimura disease**
    - Most commonly involves head and neck region
    - Less common in axilla, popliteal region, groin, and forearm

CT Findings

- **Pseudoaneurysm**
  - Arterial enhancement of lumen
  - Contrast extravasation indicates pseudoaneurysm rupture
  - Fresh hematoma around pseudoaneurysm is slightly hyperdense
  - CT reconstruction is useful for delineation of anatomy and gauging suitability for intervention

MR Findings

- **Intravascular papillary endothelial hyperplasia**
  - T1WI: Isointense mass with node-like hyperintense foci
  - T2WI: Heterogeneous hyperintense mass with node-like hypointense foci
- **Intravascular organized hematoma**
  - Signal intensity depends on age of hematoma
- **Pseudoaneurysm**
  - T1WI
    - Pseudoaneurysm luminal flow void
    - High signal in methemoglobin-containing portions of surrounding hematoma
  - MRA
    - Contrast-enhanced MRA preferred to "time-of-flight" or phase-contrast technique because of superior signal:noise ratio
    - Double to triple dose gadolinium typically used

Ultrasonographic Findings

- **Intravascular papillary endothelial hyperplasia**
  - Focal, oblong-shaped vascular dilatation with well-defined intraluminal mass
    - Mass hypoechoic compared with subcutaneous fat
    - ± hyperechoic septa
  - Color Doppler imaging
    - Central flow for larger lesions
    - Absent flow for smaller lesions
    - Septal and peripheral vascularity
- **Superficial thrombophlebitis**
  - Thrombosed vein with thickened vein wall
  - Halo of edematous hyperechoic subcutaneous fat
  - ± perivascular hyperemia
- **Venous varix**
  - Focal, easily compressible, saccular or fusiform dilatation of vein
    - Vein wall of normal caliber with normal perivascular tissues
    - ± low-level internal echoes due to turbulent flow
- **Intravascular organized hematoma**
  - Focal hypoechoic to hyperechoic lesion within vascular lumen (i.e., hematoma-like lesion within vein)
    - Mild to moderate vascular dilatation
    - No color flow on color Doppler imaging
- **Pseudoaneurysm**
  - Hypoechoic or anechoic, perivascular, saccular-shaped mass
  - Neck connects pseudoaneurysm to artery
  - Pulsed Doppler imaging
    - Characteristic "to and fro" flow pattern at neck of pseudoaneurysm
    - ± turbulent high-velocity flow if neck is narrowed
    - Flow can sometimes be detected in pseudoaneurysm neck though not in lumen
  - Color Doppler imaging
    - Characteristics ''yin-yang'' sign within lumen of pseudoaneurysm
      - Swirling flow producing different color signals within lesion
    - Lumen may be only partially filled with color signal due to partial thrombosis
      - ± slow flow within lumen
- **Kimura disease**

- Tumor arising from arterial wall
  - Fusiform-shaped, hypoechoic arterial wall thickening
    - Variable flow in thickened arterial wall on color Doppler imaging

Imaging Recommendations

- Best imaging tool
  - Ultrasound for all focal vascular abnormalities, provided vessel is accessible
- Protocol advice
  - **Intravascular papillary endothelial hyperplasia**
    - Tourniquet application is useful if arising from vein to maximal venous distension and optimally show intraluminal content
  - **Superficial thrombophlebitis**
    - Valsalva maneuver or compression augmentation can help with flow detection

DIFFERENTIAL DIAGNOSIS

Angiosarcoma or Kaposi Sarcoma

- Rarely confined to vascular wall or lumen

Angiolymphoid Hyperplasia

- Histology similar to Kimura disease
- Eosinophilia less prevalent than in Kimura disease
- IgE level is normal

PATHOLOGY

General Features

- Etiology
  - **Intravascular papillary endothelial hyperplasia**
    - Macrophage-derived fibroblast growth factor (bFGF) stimulates papillary proliferation of plump endothelial cells that release more bFGF
      - Can arise in vascular anomalies
  - **Superficial thrombophlebitis**
    - Preexisting deep venous thrombosis or cellulitis
    - Recent instrumentation
  - **Venous varix**
    - Previous trauma or surgery, valvular incompetence
  - **Intravascular organized hematoma**
    - Previous trauma
  - **Pseudoaneurysm**
    - Iatrogenic or traumatic needle puncture; infection/inflammation adjacent to artery, septic emboli
  - **Kimura disease**
    - Immunologically mediated disorder

Microscopic Features

- **Intravascular papillary endothelial hyperplasia**
  - Papillary projections composed of plump endothelial cells within fibrinous matrix and dilated vascular spaces
    - Also microthrombi in various stages of organization
- **Kimura disease**
  - Eosinophilic infiltration with microabscesses
  - Well-developed lymphoid follicles

CLINICAL ISSUES

Presentation

- Most common signs/symptoms
  - **Intravascular papillary endothelial hyperplasia**
    - Slowly growing palpable lesion, often with bluish or reddish discoloration of overlying skin ± pain
  - **Superficial thrombophlebitis**
    - Swollen and tender area in lower limb with increased warmth
  - **Venous varix**
    - Palpable, soft, fully compressible mass
  - **Intravascular organized hematoma**
    - Painful palpable lesion along course of vein
  - **Pseudoaneurysm**
    - Increased swelling, which may be pulsatile, at site of prior needle puncture, surgery, or trauma
  - **Kimura disease**
    - Painless subcutaneous mass

Demographics

- Ethnicity
  - **Kimura disease**
    - More common in the Asian population

Treatment

- **Intravascular papillary endothelial hyperplasia**
  - Complete surgical excision
- **Superficial thrombophlebitis**
  - Anti-inflammatory agents or heat therapy
- **Venous varix**
  - Pressure garment or surgery
- **Intravascular organized hematoma**
  - Conservative treatment
- **Pseudoaneurysm**
  - US-guided compression
    - Success rate ~ 90%
  - US-guided thrombin (human or bovine) injection
  - Percutaneous transarterial embolization or covered stenting
  - Surgery with direct arterial repair or bypass surgery (last resort)
- **Kimura disease**
  - Surgical excision

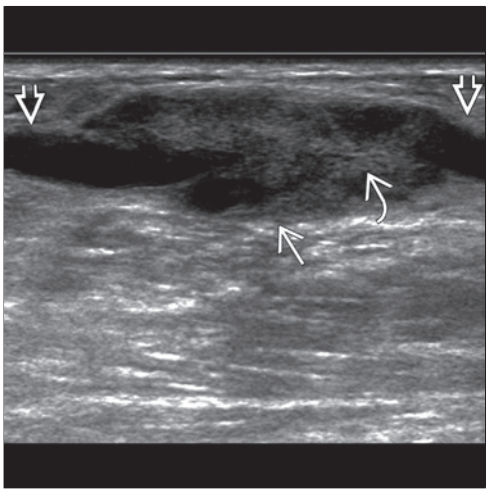
DIAGNOSTIC CHECKLIST

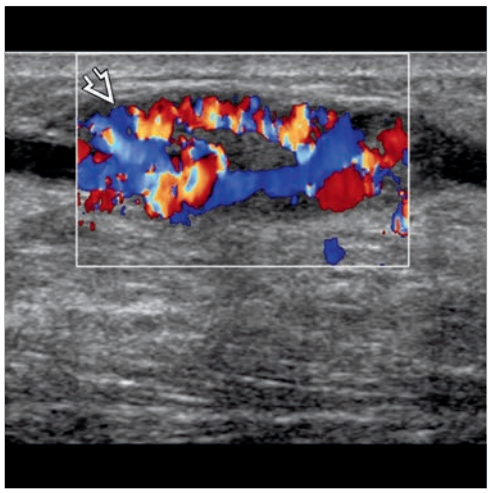
Consider

- Ultrasound is best imaging modality for all focal vascular abnormalities, provided vessel can be assessed by ultrasound

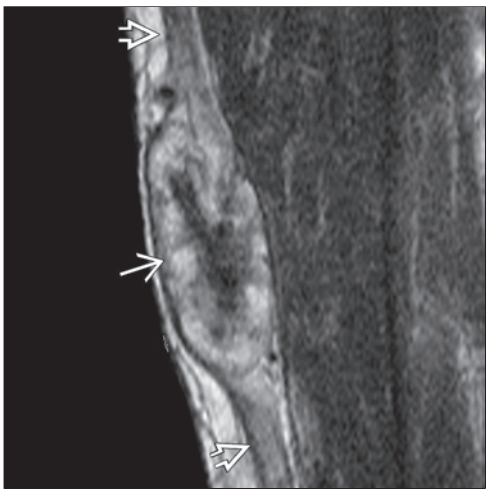
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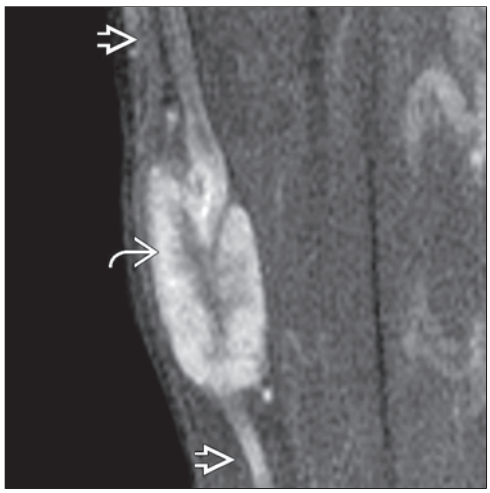
1. Paunipagar BK et al: Intravascular papillary endothelial hyperplasia: report of two cases. Acta Radiol. 52(5):499-502, 2011
2. Lee SJ et al: Imaging findings of intravascular papillary endothelial hyperplasia presenting in extremities: correlation with pathological findings. Skeletal Radiol. 39(8):783-9, 2010



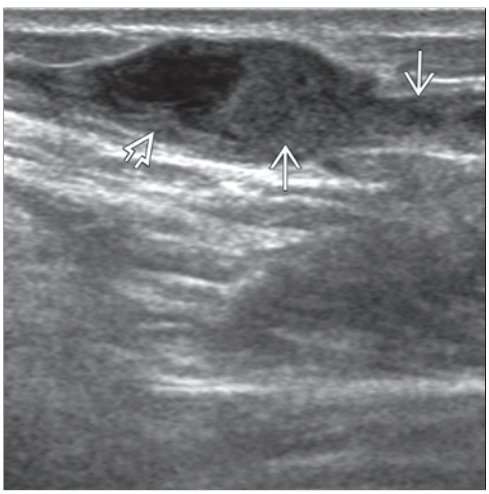


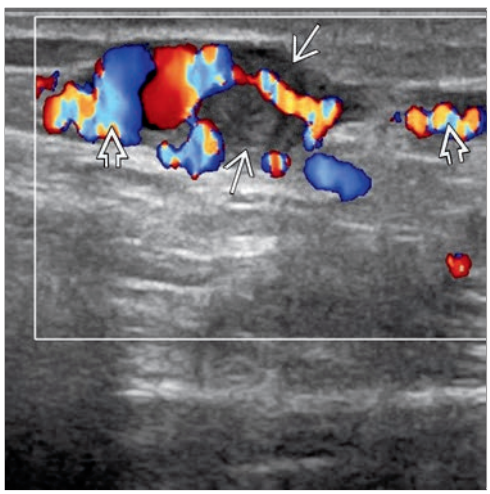
(Left) *Longitudinal ultrasound shows a focally dilated long saphenous vein on the medial aspect of the thigh. There is a mildly hypoechoic tumor within the dilated vein, compatible with histologically proven Masson tumor (intravascular papillary endothelial hyperplasia).* ***(Right)*** *Longitudinal Color Doppler ultrasound of the same tumor shows marked tumoral vascularity. This helps to differentiate the intravascular papillary endothelial hyperplasia from intravascular thrombosis.*





(Left) *Sagittal T2WI MR of the same tumor as the previous image shows the fusiform-shaped, dilated, long saphenous vein filled with heterogeneously hyperintense tumor.* ***(Right)*** *Sagittal T1WI C+ FS MR of the same tumor shows homogeneous enhancement of the Masson tumor within the long saphenous vein. This enhancement is compatible with the hyperemia seen on color Doppler imaging.*

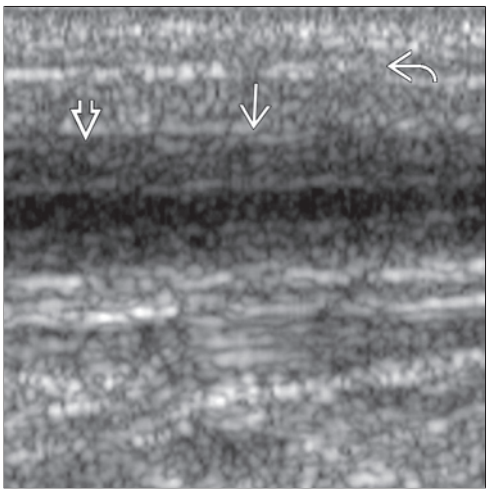


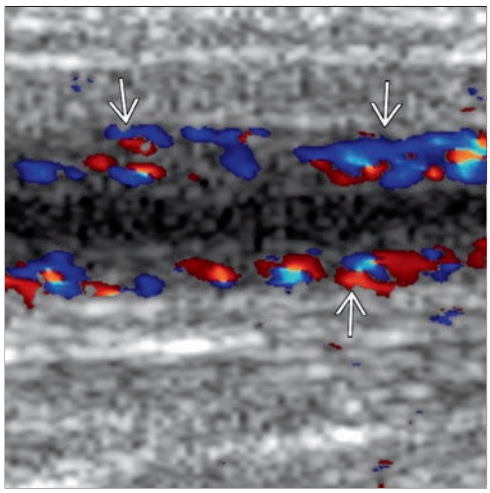


(Left) *Longitudinal ultrasound shows focal dilatation of the short saphenous vein on the medial aspect of the knee. The dilated vein and proximal venous segment is partially filled with mildly hypoechoic tissue. Histology confirmed a Masson tumor (intravascular papillary endothelial hyperplasia).* ***(Right)*** *Longitudinal color Doppler ultrasound of the same tumor shows no tumoral vascularity, which is an atypical feature. There is flow within the short saphenous vein.*

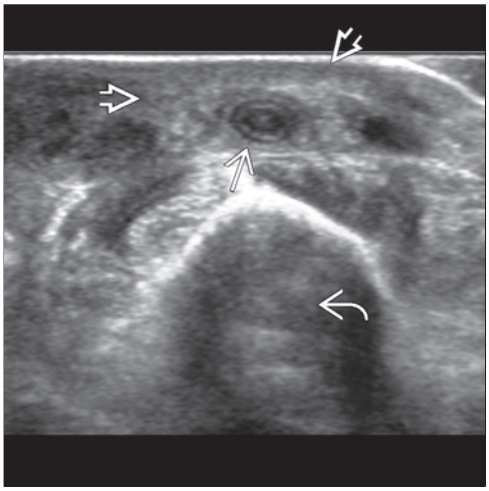
VASCULAR DILATATION OR INFLAMMATION

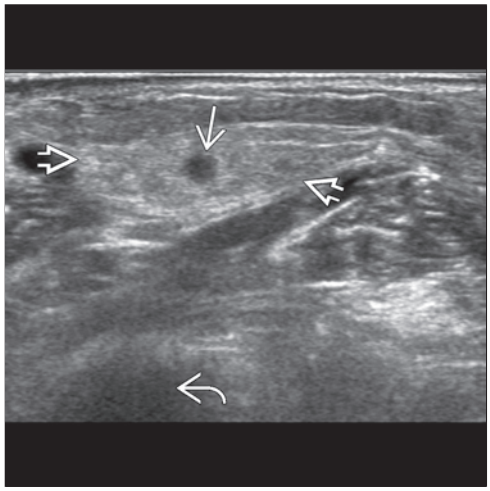
(Left) *Longitudinal ultrasound shows thrombophlebitis of a short saphenous vein in the lower calf. There is dilatation and thrombosis of the vein with severe thickening of the venous wall and adjacent mild inflammation.* ***(Right)*** *Longitudinal color Doppler ultrasound of the same vein shows moderate hypervascularity of the thickened venous wall. There is no flow within the vein.*



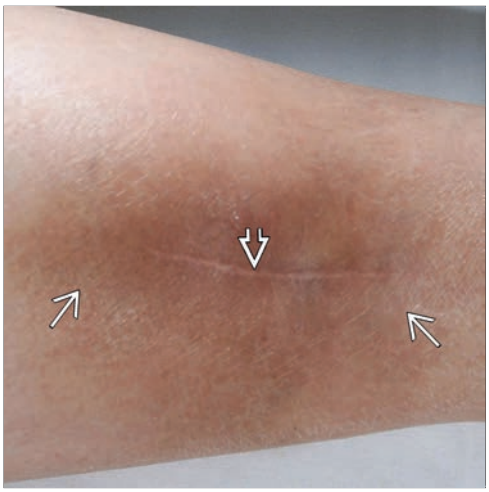


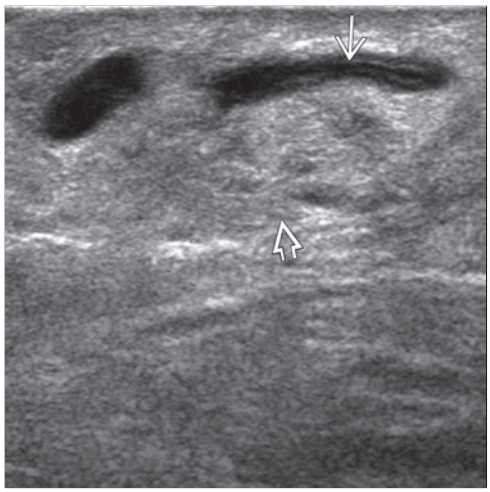
(Left) *Longitudinal ultrasound shows superficial thrombophlebitis on the lateral aspect of the forearm with a dilated, thrombosed, thick-walled vein and moderate perivenous subcutaneous soft tissue edema. The radius is normal.* ***(Right)*** *Transverse ultrasound shows superficial thrombophlebitis on the volar aspect of the proximal forearm. There is a mildly dilated vein with moderate adjacent subcutaneous edema centered around the vein. The radial head is normal.*

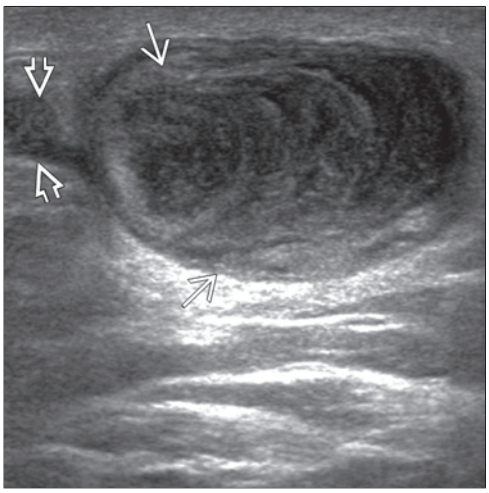


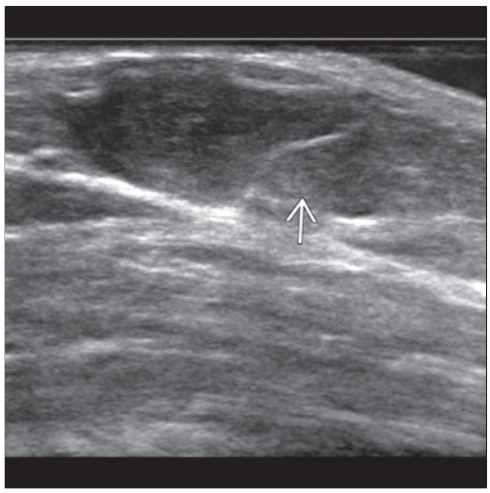


(Left) *Clinical photograph of a leg shows redness and swelling that had developed over the previous week around the site of a subcutaneous lipoma excision performed 1 year earlier.* ***(Right)*** *Longitudinal ultrasound of the same area shows mild subcutaneous vein dilatation with moderate adjacent subcutaneous edema and hyperemia (not shown) indicative of cellulitis. This is primary cellulitis, not centered around the vein, rather than primary superficial thrombophlebitis.*

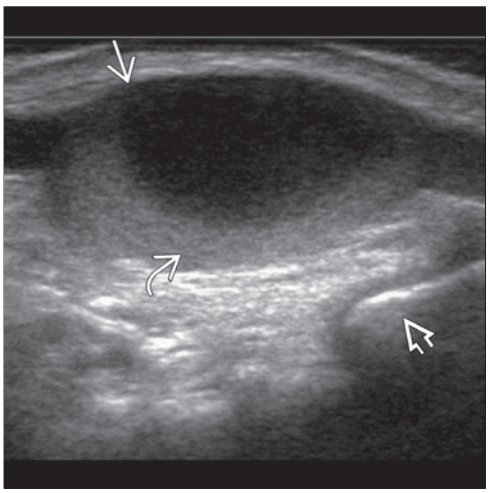


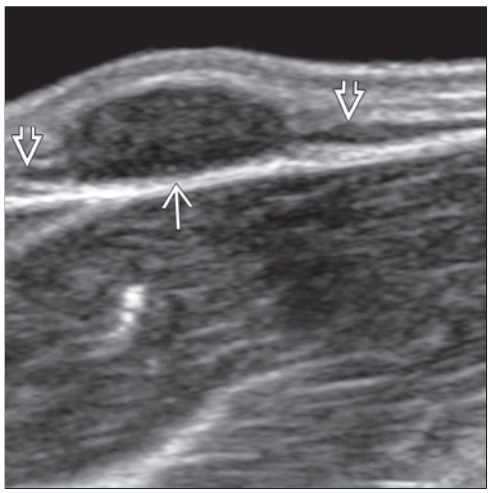




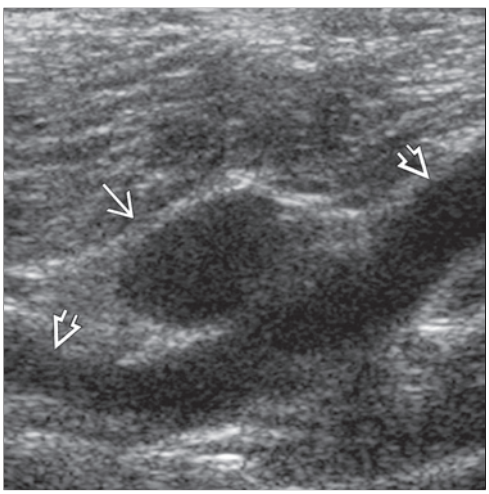


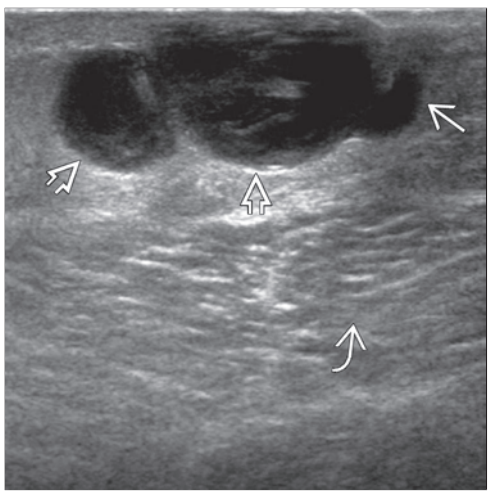
(Left) *Longitudinal ultrasound shows an organized intravascular hematoma on the volar aspect of the elbow. The hematoma causes focal dilatation of the superficial vein.* ***(Right)*** *Longitudinal color Doppler ultrasound shows an intravascular organized hematoma within the long saphenous vein in the thigh. No internal vascularity is present within the hematoma.*





(Left) *Longitudinal ultrasound shows a venous varix on the dorsal aspect of the wrist. There is partially stagnant flow within the varix, which mimics a hypoechoic mass. Dynamic ultrasound with compression/decompression revealed movement within this stagnant flow area. The distal radius is normal.* ***(Right)*** *Longitudinal ultrasound shows a fusiform-shaped venous varix along a superficial vein on the medial aspect of the elbow. The luminal hyperechogenicity is due to slow moving red cell aggregates.*

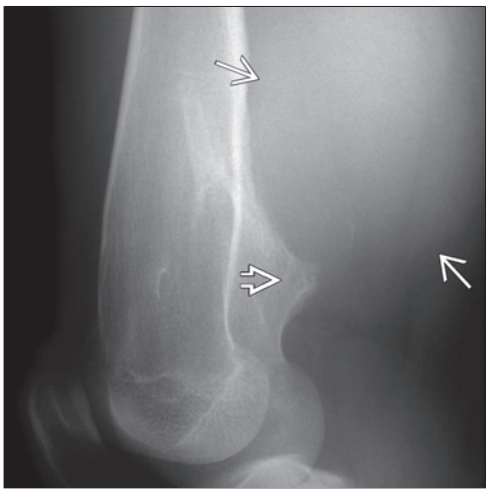


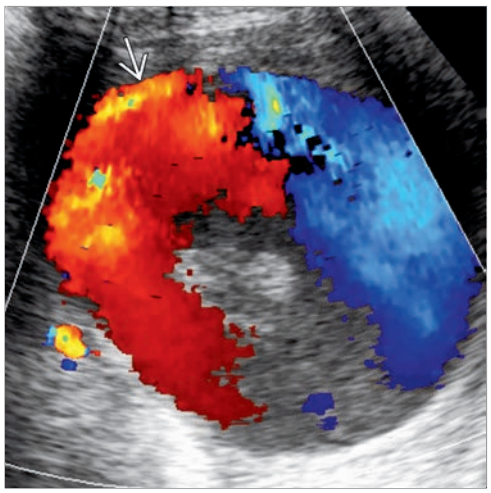


(Left) *Longitudinal ultrasound shows a saccular venous outpouching from the popliteal vein in the popliteal fossa, consistent with a venous varix.* ***(Right)*** *Longitudinal ultrasound shows a lobulated venous varix arising from a superficial femoral vein on the medial aspect of the distal thigh. The varix lies superficial to the sartorius muscle and is easily compressible. The echogenic content represents sluggish blood flow with rouleaux formation of red blood cells.*

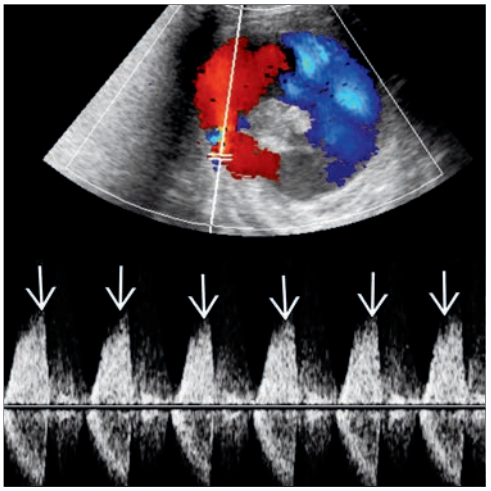
VASCULAR DILATATION OR INFLAMMATION

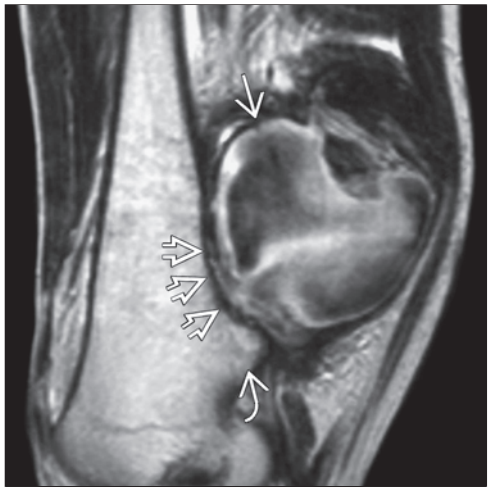
(Left) *Lateral radiograph shows soft tissue swelling ➔ on the posterior aspect of the distal thigh with an osteochondroma ➔ in the metaphysis of the distal femur. A malignant transformation was suspected clinically.* ***(Right)*** *Transverse color Doppler ultrasound of the same patient shows a large pseudoaneurysm ➔ arising from the superficial femoral artery on the posterolateral aspect of the thigh. There is swirling color flow ("yin-yang" sign) within the pseudoaneurysm lumen.*



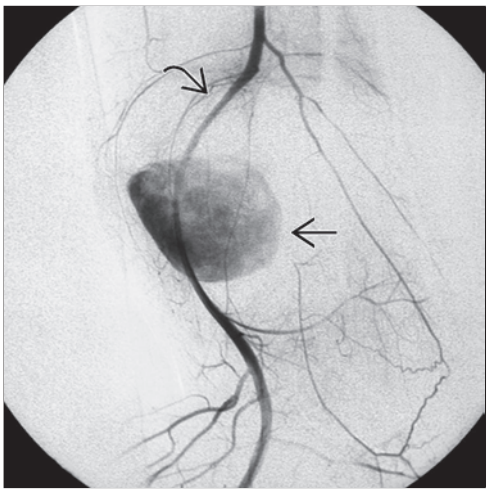


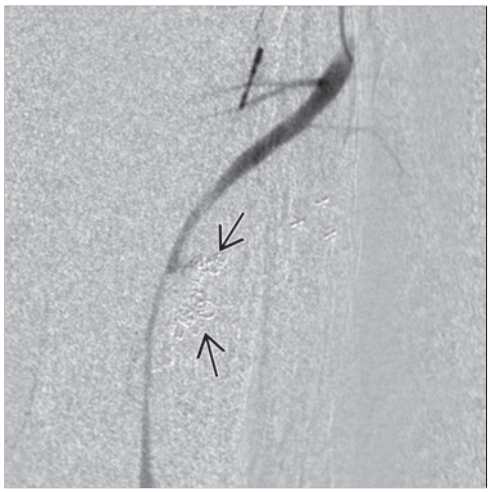
(Left) *Transverse power Doppler ultrasound of the same patient shows "to and fro" arterial flow ➔ within the neck of the pseudoaneurysm.* ***(Right)*** *Sagittal T2WI MR of the same lesion shows the large pseudoaneurysm ➔ with flow void similar to the "yin-yang" sign in the posterior aspect of the thigh. The pseudoaneurysm causes scalloping of the distal femur ➔ as well as truncation of the osteochondroma ➔.*

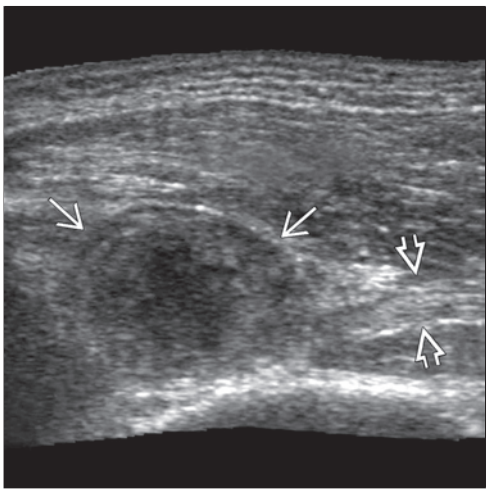


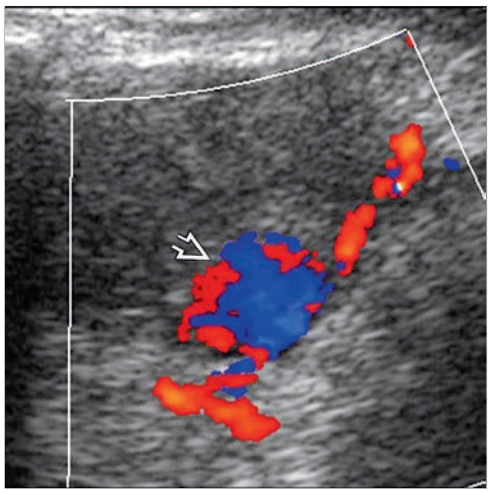


(Left) *Anteroposterior digital subtraction angiography (DSA) in the same patient shows the pseudoaneurysm ➔ arising from a displaced and narrowed superficial femoral artery ➔. Angiographic embolization was subsequently performed (not shown).* ***(Right)*** *Anteroposterior DSA of the same lesion following embolization shows complete obliteration of the pseudoaneurysm by embolization coils ➔.*

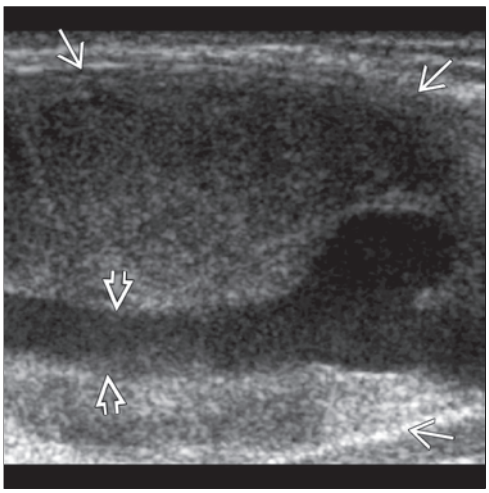


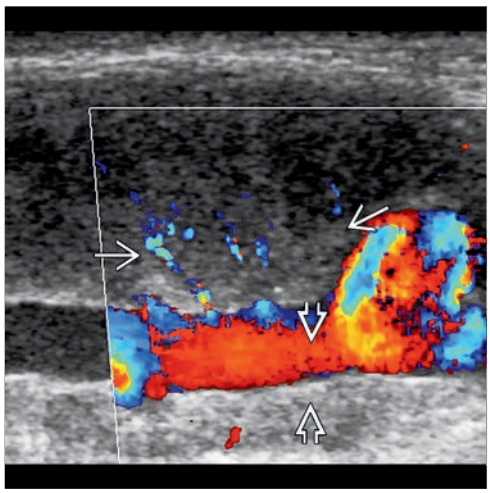




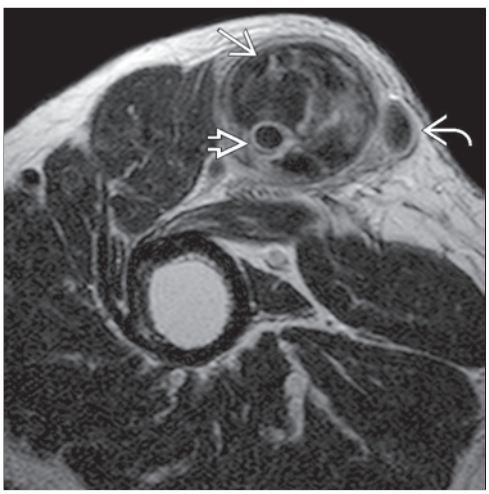


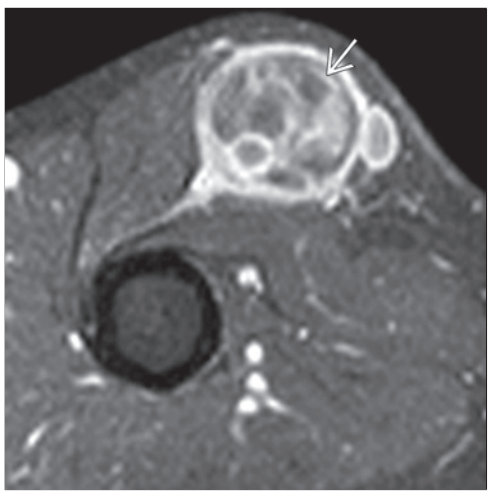
(Left) *Longitudinal ultrasound of the buttock in a patient with a recent stab injury to the buttock region shows a pseudoaneurysm ➡ of the superior gluteal artery. The adjacent sciatic nerve ➡ is moderately compressed by the pseudoaneurysm.* ***(Right)*** *Color Doppler ultrasound of the same patient shows swirling, turbulent flow within the pseudoaneurysm sac ➡. Transarterial embolization was subsequently performed (not shown) with rapid alleviation of sciatica-type symptoms.*



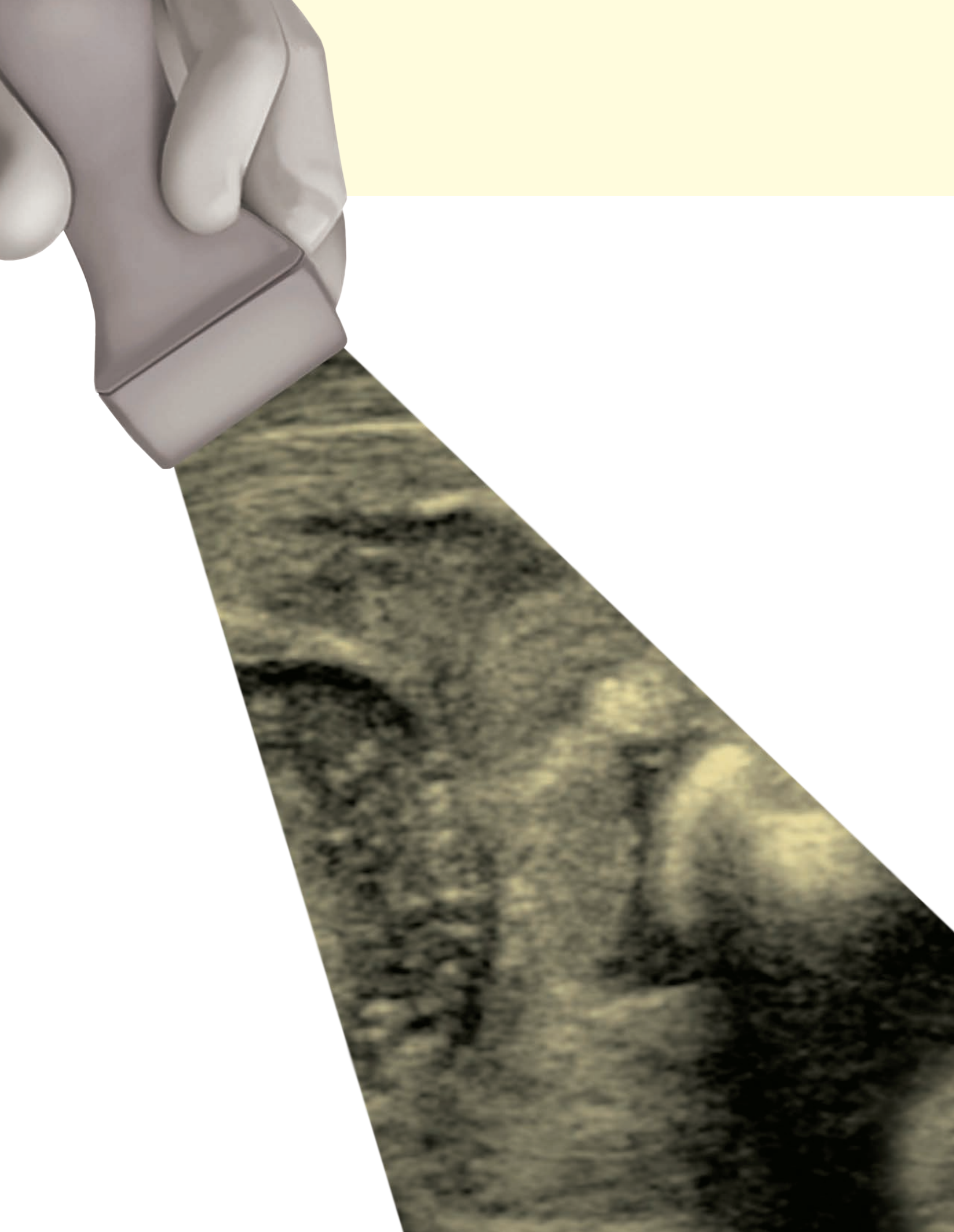


(Left) *Longitudinal oblique ultrasound reveals a thick hypoechoic mass ➡ arising from the arterial wall of the proximal brachial artery ➡.* ***(Right)*** *Longitudinal oblique color Doppler ultrasound shows mild internal vascularity ➡ of the hypoechoic mass supplied by arterioles arising from the brachial artery lumen ➡. Ultrasound-guided percutaneous biopsy of the arterial wall revealed Kimura disease.*





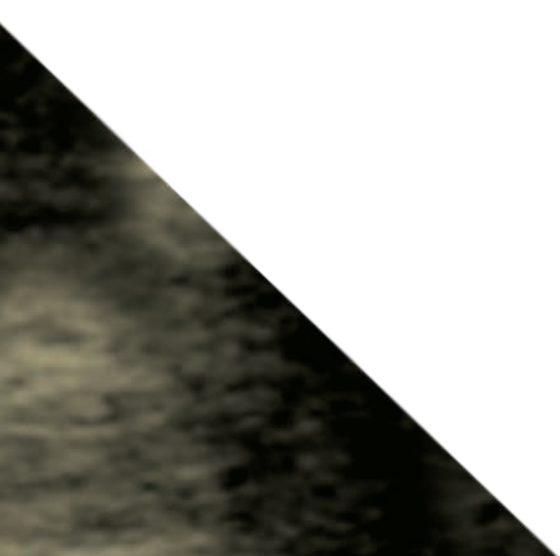
(Left) *Axial T2WI MR of the same patient as previous image shows a heterogeneous hypointense mass ➡ due to Kimura disease arising largely eccentrically from the wall of the brachial artery ➡. The brachial vein ➡ is normal.* ***(Right)*** *Axial T1WI C + FS MR of the same patient shows mild heterogeneous enhancement of the Kimura disease mass ➡. Segmental brachial artery excision was performed followed by arterial repair.*



SECTION 6

Infection

Soft Tissue Infection **II**-6-2
Bone Infection **II**-6-10
Joint Infection **II**-6-20
Postoperative Infection **II**-6-26



SOFT TISSUE INFECTION

Key Facts

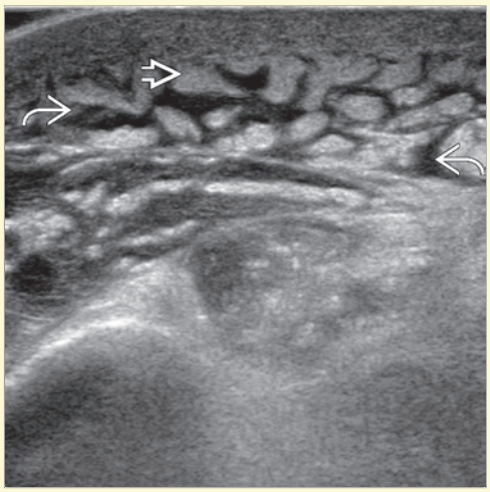
Terminology

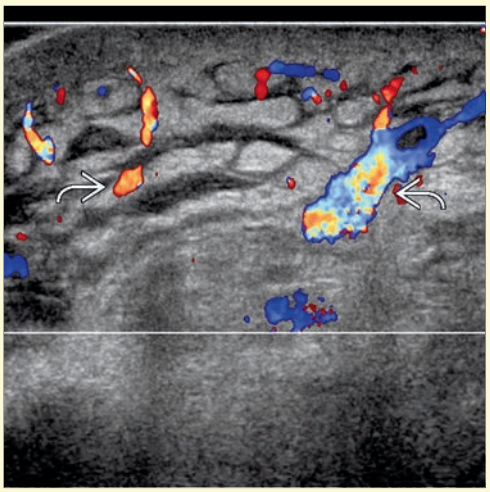
- Infection of soft tissue including cellulitis, infective fasciitis, necrotizing fasciitis, pyomyositis, phlegmon, and abscess

Imaging

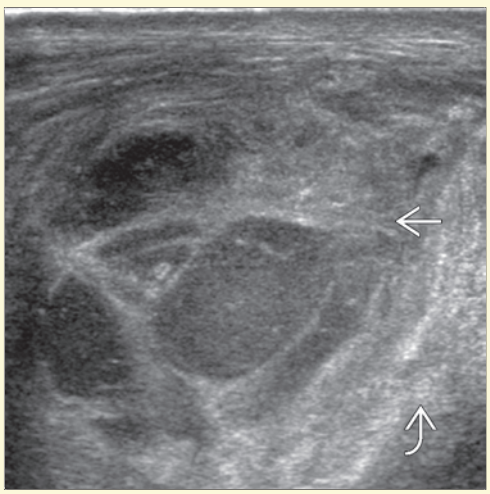
- **Cellulitis**
  - Edematous hyperechoic subcutaneous fat with hyperemia
  - Thickened interlobular septa
- **Necrotizing fasciitis**
  - Thickened fascia with perifascial fluid (fluid above and below investing fascia)
  - Severe associated subcutaneous and muscle edema
  - ± fascial irregularity or focal defect ± muscle necrosis ± gas locules with "comet tail" or shadowing artifact
- **Pyomyositis**
  - Diffuse edematous hyperechoic muscle swelling with indistinct fibrillary pattern
  - Hyperemia ± gas locules with "comet tail" or shadowing artifact
- **Abscess**
  - Depending on maturity and content, echogenicity of fluid may vary from hypoechoic to isoechoic to hyperechoic
  - Posterior enhancement characteristic
  - Echo movement on real-time imaging
  - Peripheral hyperemia ± septation ± gas locules with "comet tail" or shadowing artifact
- US ± US-guided aspiration gives sufficient information to make prompt diagnosis and guide treatment; US cannot distinguish infective from noninfective fluid
- Routinely assess with color Doppler imaging

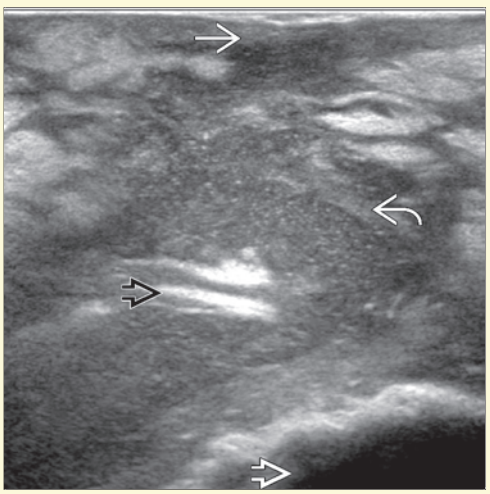
(Left) *Transverse ultrasound of ankle region shows severe subcutaneous tissue thickening and edema. There is fluid leading to thickened interlobular septa with intervening hyperechoic fat lobules.* ***(Right)*** *Transverse color Doppler ultrasound of the same patient shows moderate severity hyperemia. This hyperemia allows distinction between noninflamed and inflamed subcutaneous tissue edema, i.e., cellulitis.*





(Left) *Transverse ultrasound of the posterior thigh shows a multiloculated intramuscular abscess within the semimembranosus muscle. This is associated with marked surrounding soft tissue edema.* ***(Right)*** *Transverse ultrasound of the buttock region in a tetraplegic patient shows extensive soft tissue edema with ill-defined abscess formation overlying the ischial tuberosity and extending to a cutaneous opening. There is a linear hyperechoic gas artifact present within the abscess.*





SOFT TISSUE INFECTION

TERMINOLOGY

Definitions
- Cellulitis: Localized or diffuse soft tissue inflammation of skin and subcutaneous tissues
- Infective fasciitis: Infection of superficial &/or deep fascia
- Necrotizing fasciitis: Rapidly progressive infection of superficial and deep fascia associating with vascular occlusion and necrosis
- Pyomyositis: Infective myositis = suppurative bacterial infection of muscle
- Phlegmon: Localized intense inflammation prior to development of abscess or ulceration
- Abscess: Localized collection of pus

IMAGING

General Features
- Best diagnostic clue
  - Edema and hyperemia of affected tissues ± fluid accumulation
- Location
  - Any soft tissue tissue can become infected
  - Most common sites
    - Cellulitis: Dorsum of hands and feet
    - Necrotizing fasciitis: Thigh and leg
    - Pyomyositis: Large muscles of pelvis and lower limb; frequently multifocal
- Size
  - Varies from small localized abscess to multicompartmental disseminated infection
- Morphology
  - Inflammation ± fluid ± abscess

Radiographic Findings
- Often noncontributory
- Soft tissue swelling with obliteration of fascial planes
  - ± gas locules within soft tissues ± radiopaque foreign body ± concomitant osteitis or osteomyelitis

CT Findings
- Increased attenuation of subcutaneous fat
- Swelling of subcutaneous tissue ± muscles
- Fascial thickening or perifascial fluid
- ± gas locules within soft tissues ± foreign body ± concomitant osteitis or osteomyelitis
- Contrast enhancement is useful in detecting fluid collection, abscess, or necrosis

MR Findings
- T2WI FS
  - Cellulitis: Diffuse hyperintensity of subcutaneous tissues
    - ± feathery edema of adjacent tissues
  - Necrotizing fasciitis: Hyperintense thickening of fascia with perifascial fluid
    - Edema of adjacent musculature
    - ± fluid areas indicative of necrosis, exudate, or abscess
    - ± hypointense foci due to gas locules
  - Pyomyositis: Diffuse hyperintensity of muscle
    - ± fluid collection
    - ± edematous changes in adjacent subcutaneous tissue > fascial planes > bone and joints
  - Abscess: High signal intensity area with surrounding edema ± hyperemia
    - ± hypointense foci due to gas locules
- T1WI C+
  - Useful in delineating fluid collection, abscess, or necrosis

Ultrasonographic Findings
- **Cellulitis**
  - Edema and hyperemia of subcutaneous fat
    - Edematous fat is echogenic on ultrasound
    - Thickened interlobular septa
    - ± periseptal fluid, and fluid around investing fascia
    - Need combination of edema and hyperemia to diagnose cellulitis
      - Hyperemia is not seen with noninflammatory edema in, for example, venous insufficiency, heart failure, or lymphoedema
    - ± secondary tenosynovitis with mild synovial proliferation and tendon thickening
  - Appearance of subcutaneous edema varies according to severity and architecture of subcutaneous fat
    - Varies from amorphous swelling with indistinct lobules to cobblestone appearance with accentuated lobules
- **Necrotizing fasciitis**
  - Affects subcutaneous fat, fascia, and muscle
  - Thickened fascia with perifascial fluid (fluid above and below investing fascia)
    - ± fascial irregularity or focal defect
  - Severe associated subcutaneous and muscle edema
  - ± muscle necrosis (difficult to detect)
  - Gas locules with "comet tail" artifacts or shadowing artifact are suggestive of necrosis
- **Pyomyositis**
  - Diffuse muscle swelling with edema ± hyperemia
  - Edematous muscle is echogenic on ultrasound
  - Indistinct fibrillary pattern of muscle
  - ± focal hypoechoic areas due to serous exudate, abscess, or necrosis
- **Abscess**
  - Posterior enhancement characteristic
  - Depending on maturity and content, echogenicity of fluid may vary from hypoechoic → isoechoic → hyperechoic
    - If thick fluid or debris present, may mimic solid mass, so best to have low threshold for aspiration, as fluid is not readily discernible
  - Echo movement on real-time imaging
  - ± gas locules with "comet tail" artifact or shadowing artifact
  - ± septations
  - Wall thickness is proportional to chronicity of abscess
  - ± peripheral hyperemia
- Ultrasound-guided aspiration of fluid for culture and sensitivity
  - Occasionally, little or no fluid can be aspirated despite visibly moving echoes

Imaging Recommendations
- Best imaging tool

SOFT TISSUE INFECTION

- Ultrasound ± ultrasound-guided aspiration gives sufficient information to make prompt diagnosis and guide treatment
- Protocol advice
  - Routinely assess with color Doppler imaging
  - Look for focal hypoechoic areas representing fluid collection, abscess, or necrosis
    - If fluid is present, consider aspiration for culture
    - Imaging cannot distinguish between infective and noninfective fluid
  - ± percutaneous biopsy of cellulitis for culture

DIFFERENTIAL DIAGNOSIS

Subcutaneous Edema
- Similar to cellulitis
- Hyperechoic fat and thickened interlobular septa
- No hyperemia

Muscle Hematoma
- Similar to muscle abscess
- Hypoechoic mass with posterior enhancement, variable liquefaction, and surrounding edema
- Less inflammatory component with hematoma

Muscle Infarction
- Similar to focal pyomyositis
- Hypoechoic mass with surrounding edema and hyperemia
- Less inflammatory component with infarction

PATHOLOGY

General Features
- Etiology
  - Predisposing conditions
    - Old age, immunosuppression, illicit drug abuse, systemic inflammatory disease, peripheral vascular disease, trauma, surgery, obesity, alcoholism, malnutrition
  - Route of infection
    - Loss of skin integrity from trauma, surgery, or diabetic ulceration; hematogenous route is less common
  - Causative organisms
    - Usually polymicrobial with combination of aerobic and anaerobic organisms; fungal and atypical organism are sometimes seen
    - Cellulitis: *Streptococcus pyogenes*, *Staphylococcus aureus*
    - Necrotizing fasciitis: Group A β-hemolytic streptococci
    - Pyomyositis: *S. aureus*, *Mycobacterium tuberculosis*, *Nocardia asteroides*, *S. pyogenes*, *Streptococcus viridans*, *Cryptococcus neoformans*

Gross Pathologic & Surgical Features
- Cellulitis
  - Acute inflammatory reaction
- Necrotizing fasciitis
  - Facilitated by enzymes, bacteria spread from subcutaneous tissues to investing and deep fascia and then muscle
    - Induces vascular thrombosis → tissue necrosis
    - Superficial nerve ischaemia → characteristic local anesthesia
- Pyomyositis
  - Bacterial infection of skeletal muscle ± necrosis or abscess

Microscopic Features
- Cellulitis: Acute inflammatory infiltrate, capillary dilatation ± abscess formation
- Necrotizing fasciitis: Fascial inflammation and necrosis, subcutaneous fat necrosis, arterial thrombi, vasculitis, and myonecrosis
- Pyomyositis: Acute inflammatory infiltrate, capillary dilatation ± abscess formation

CLINICAL ISSUES

Presentation
- Most common signs/symptoms
  - Cellulitis
    - Inflammation: Redness, heat, swelling, pain and dysfunction ± lymphangitis, blistering necrosis ± lymphadenopathy
  - Necrotizing fasciitis
    - Rapidly progressive condition with severe inflammation of tissues
    - ± blistering necrosis, cyanosis, severe tenderness, high fever, tachycardia, hypotension, impaired consciousness
  - Pyomyositis
    - Deep pain, tenderness ± mass

Demographics
- Age
  - More common in older patients
- Gender
  - M:F = 1:1
- Epidemiology
  - Cellulitis much more common than pyomyositis
  - Pyomyositis more common than necrotizing fasciitis

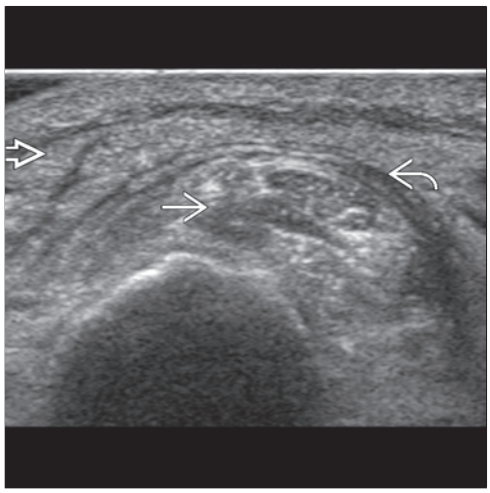
Natural History & Prognosis
- Cellulitis: Responds well to treatment
- Necrotizing fascitis: Mortality up to 25%
- Pyomyositis: Less favorable response in immunocompromised patients

Treatment
- Cellulitis: Elevation, splinting + antibiotic therapy
- Necrotizing fascitis: Early radical surgical debridement + irrigation + antibiotic therapy
- Pyomyositis: Antibiotic therapy
  - Abscess: Ultrasound-guided percutaneous aspiration or catheter drainage; surgical incision and drainage

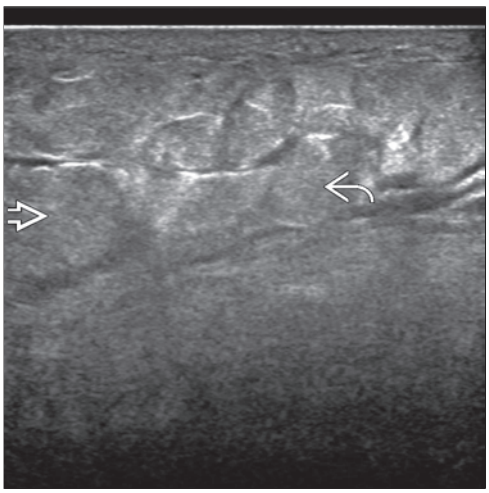
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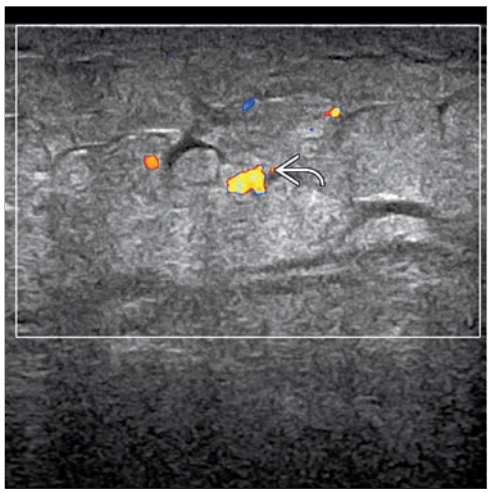
1. Oelze L et al: Emergency ultrasonography for the early diagnosis of necrotizing fasciitis: a case series from the ED. Am J Emerg Med. 31(3):632, 2013
2. Turecki MB et al: Imaging of musculoskeletal soft tissue infections. Skeletal Radiol. 39(10):957-71, 2010
3. Chau CL et al: Musculoskeletal infections: ultrasound appearances. Clin Radiol. 60(2):149-59, 2005



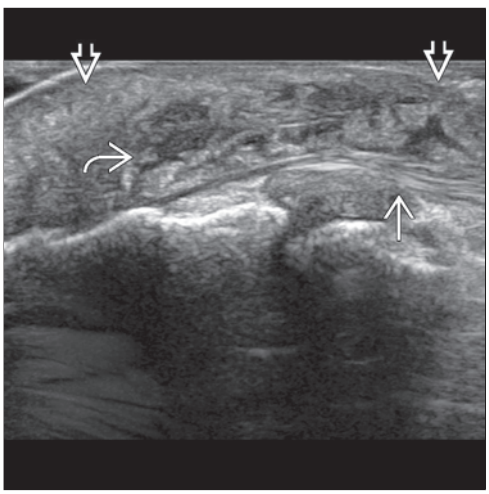


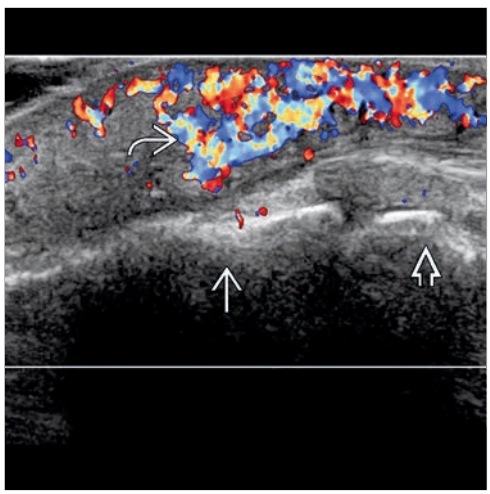
(Left) *Clinical photo of a patient with ankle swelling and fever shows soft tissue swelling and skin erythema over the lateral aspect of the ankle.* ***(Right)*** *Transverse ultrasound of the same patient shows moderate subcutaneous edema on the lateral aspect of ankle. Mild edematous thickening of the superior peroneal retinaculum, but no subfascial extension, is present. The peroneal tendons are normal. Color Doppler imaging revealed hyperemia, consistent with subcutaneous cellulitis.*





(Left) *Transverse ultrasound of the ankle region shows severe subcutaneous edema with diffuse increase in echogenicity of subcutaneous fat. The fat lobules are indistinct.* ***(Right)*** *Transverse color Doppler ultrasound of the same patient shows mild hyperemia of the subcutaneous tissues consistent with moderate-severity cellulitis. Hyperemia helps differentiate cellulitis from noninfective causes of ankle edema, such as heart failure.*

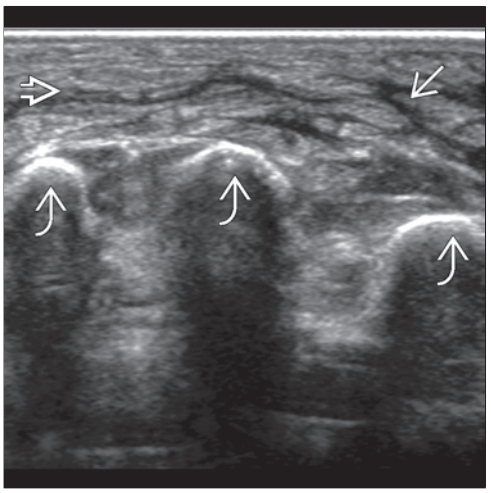


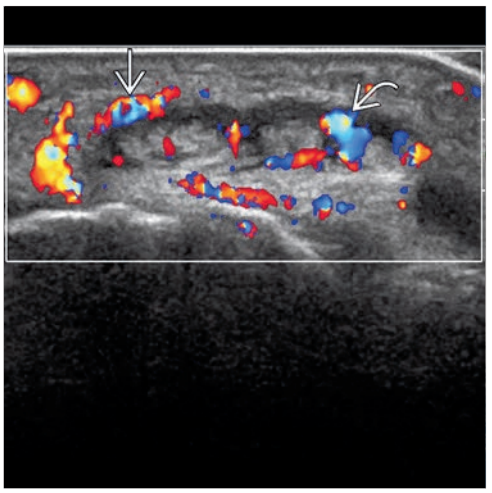


(Left) *Longitudinal ultrasound of the palmar aspect of thumb shows the presence of severe subcutaneous soft tissue thickening and edema. Linear hypoechoic areas representing edematous interlobular septa are present. No focal fluid collection is present. The flexor pollicis longus tendon is normal.* ***(Right)*** *Longitudinal color Doppler ultrasound of the same patient shows severe hyperemia indicative of severe cellulitis. The distal and proximal phalanges are normal.*

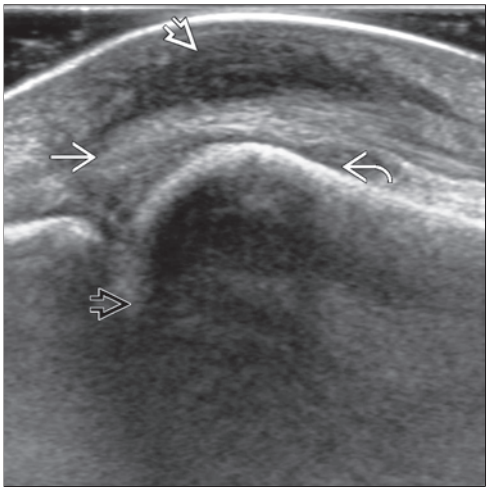
SOFT TISSUE INFECTION

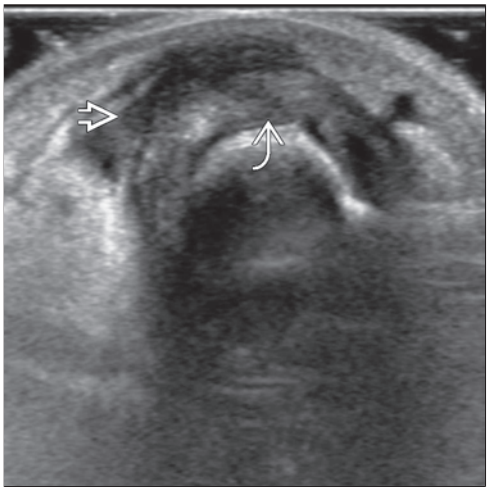
(Left) *Transverse ultrasound of a patient with extensive hand swelling and erythema shows severe subcutaneous soft tissue thickening with edematous interlobular septa on the dorsum of the hand. The metacarpal shafts are normal.* ***(Right)*** *Transverse color Doppler ultrasound of the same patient shows severe subcutaneous and peritendinous soft tissue hyperemia indicative of primary severe cellulitis with secondary tenosynovitis.*



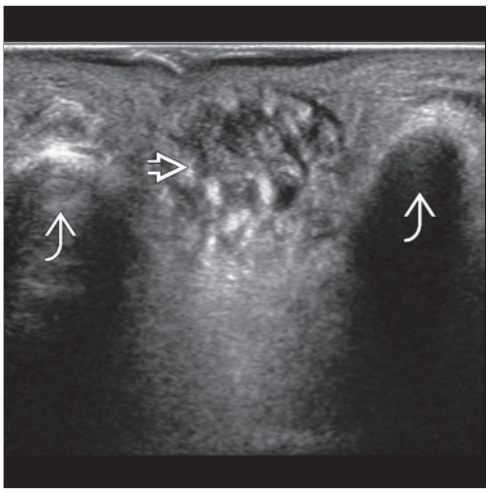


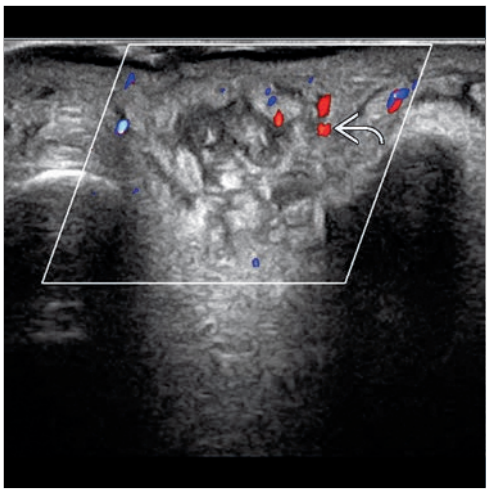
(Left) *Longitudinal ultrasound of the index finger in a patient with a recent cat bite to the index finger shows severe cellulitis, mainly superficial to but also deep to the extensor tendon at the metacarpophalangeal joint level.* ***(Right)*** *Transverse ultrasound of the same patient shows the inflammation surrounding the extensor tendon. The extensor tendon is moderately swollen, indicative of cellulitis involving both the subcutaneous tissues and the extensor tendon.*

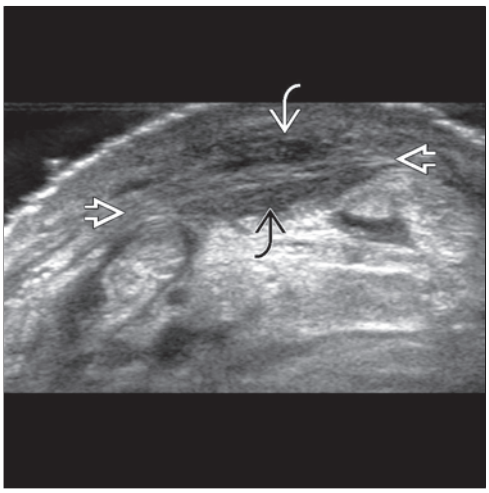


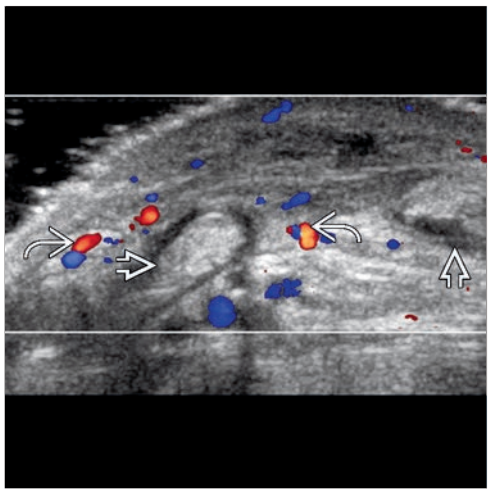


(Left) *Transverse ultrasound of a patient with forefoot cellulitis shows diffuse soft tissue edema with a relatively well-defined and localized area of hypoechogenicity present between the metatarsal shafts.* ***(Right)*** *Transverse color Doppler ultrasound in the same patient shows mild hyperemia around the hypoechoic area. The appearances are those of a phlegmonous preabscess inflammatory mass. Follow-up ultrasound in a few days would be helpful if symptoms do not settle.*

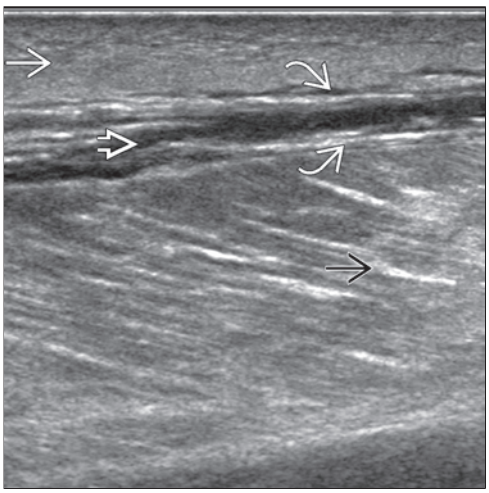


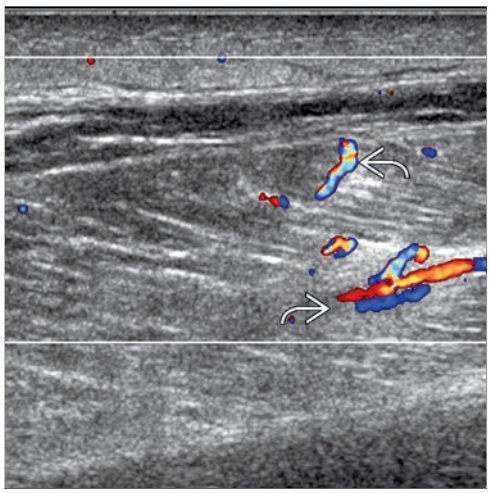




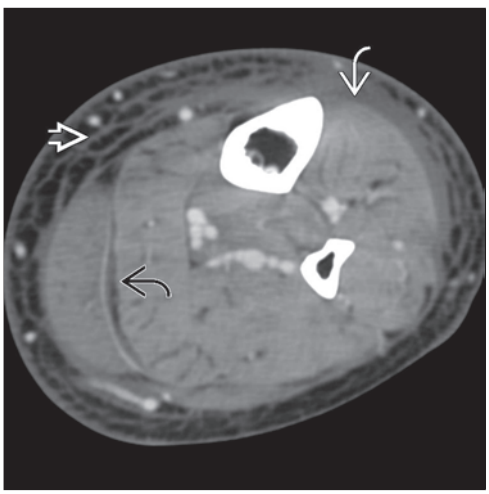


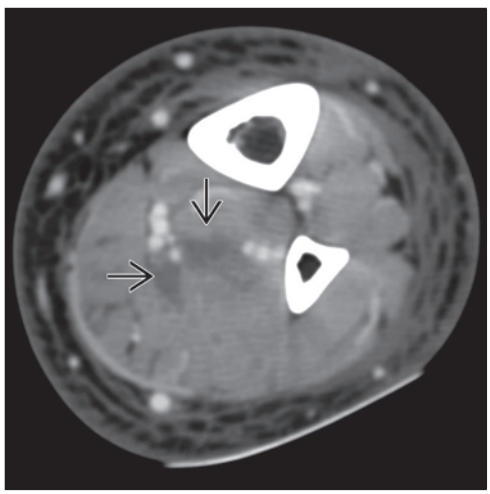
(Left) *Transverse ultrasound of the anterior ankle shows a localized area of fascial thickening with adjacent hypoechoic inflammatory tissue involving the subcutaneous and subfascial tissues.* ***(Right)*** *Transverse color Doppler ultrasound of the same patient shows mild associated soft tissue hyperemia. As this inflammation is centered on the fascia, it is termed an infective fasciitis. There is mild extensor tendon sheath thickening.*





(Left) *Longitudinal ultrasound of the calf region shows severe thickening and edema of the investing fascia overlying gastrocnemius muscle associated with perifascial fluid as well as moderate subcutaneous and muscle edema.* ***(Right)*** *Longitudinal color Doppler ultrasound of the same area shows gastrocnemius muscle hyperemia. This represents an infective fasciitis with surrounding cellulitis and myositis rather than a necrotizing fasciitis as there is no necrosis.*

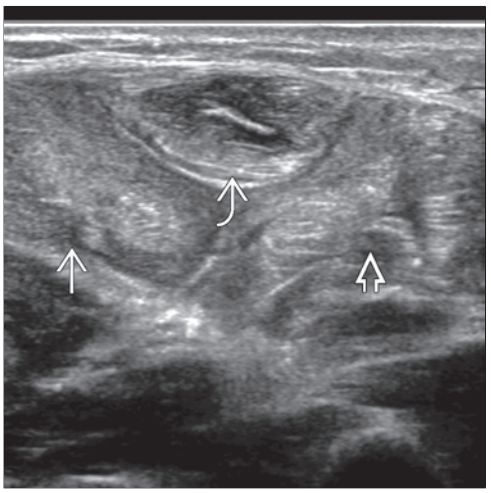


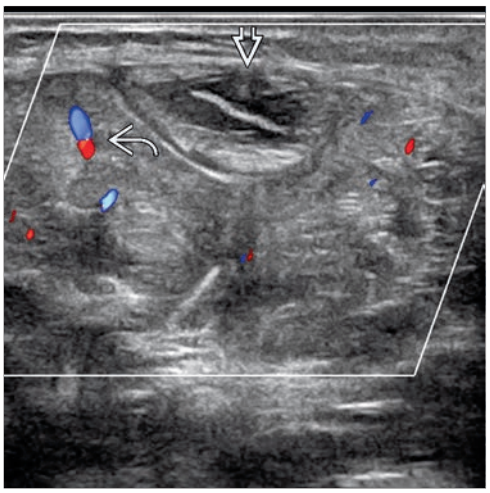


(Left) *Axial CECT of the distal leg in a patient with acute leg swelling and septicemia shows diffuse increased attenuation and stranding of the subcutaneous fat. There is also moderate generalized edema with fluid tracking along the superficial and deep fascia of the calf.* ***(Right)*** *Axial CECT of the same patient shows ill-defined nonenhancing muscle areas indicative of early muscle necrosis. The overall appearances are consistent with necrotizing fasciitis.*

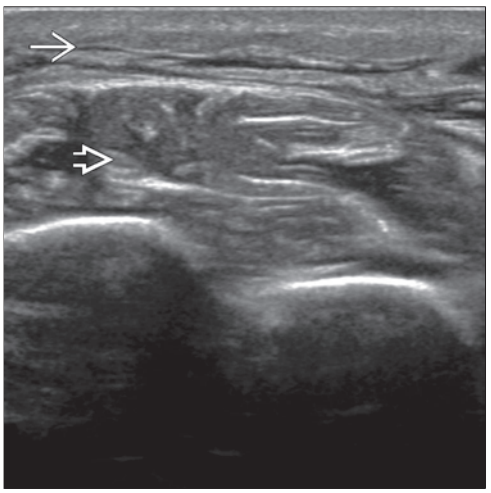
SOFT TISSUE INFECTION

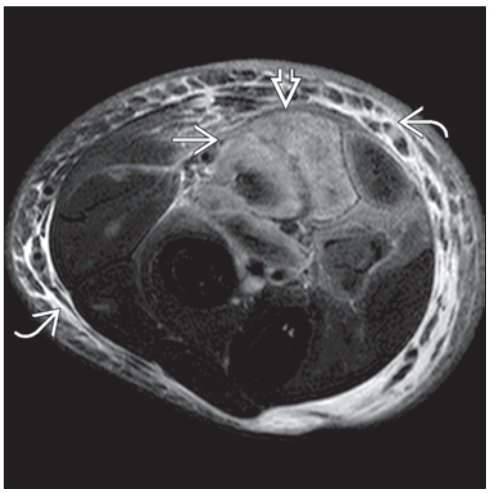
(Left) *Transverse ultrasound of the forearm in a patient with clinically progressive cellulitis shows severe edema of the flexor carpi radialis, palmaris longus, and flexor digitorum superficialis muscles. Mild to moderate subcutaneous edema is present.* ***(Right)*** *Transverse color Doppler ultrasound of the same patient shows mild hyperemia within the flexor muscles. Note the relative normal appearance of the palmaris longus muscle close to the central tendon.*



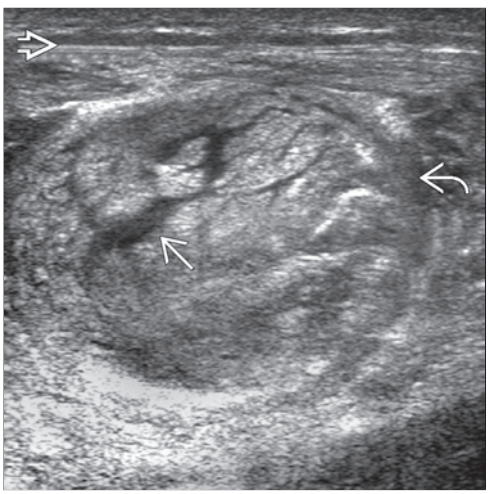


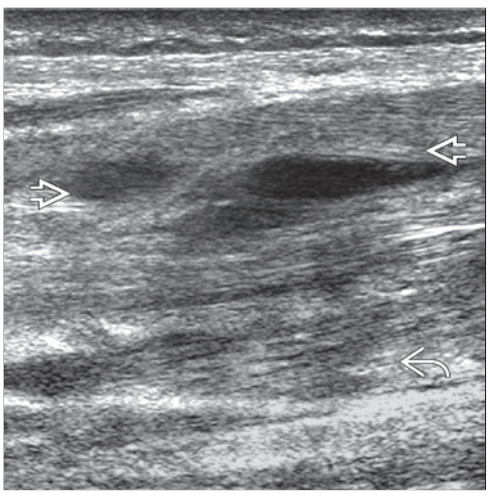
(Left) *Transverse ultrasound of the dorsal forearm of the same patient as previous image shows normal extensor musculature with moderate subcutaneous edema.* ***(Right)*** *Axial T1 C+ substraction MR shows increased flexor muscle enhancement, most severely affecting the flexor carpi radialis muscle, consistent with pyomyositis. Pyomyositis is typically multifocal. Note the diffuse subcutaneous tissue edema indicative of associated cellulitis.*

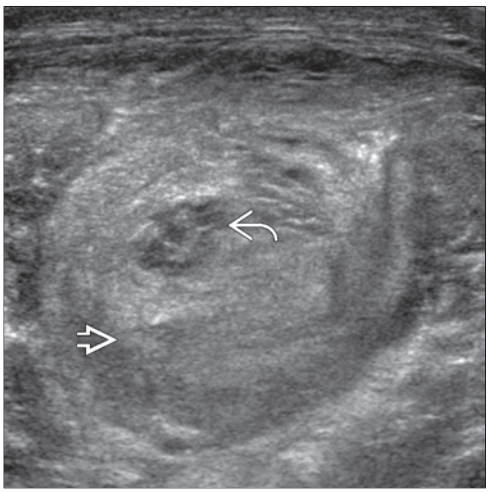


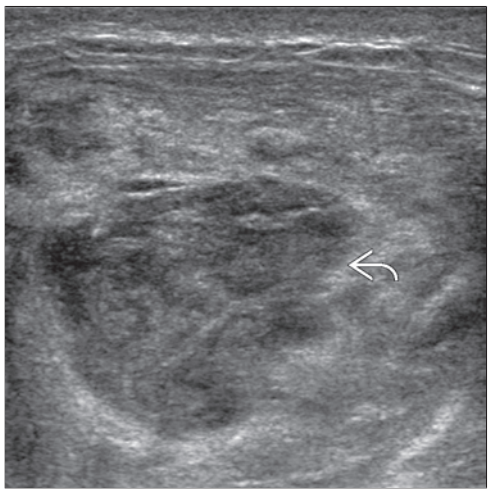


(Left) *Transverse ultrasound in an immunocompromised patient shows severe subcutaneous edema with severe semimembranosus muscle edema. There is fluid tracking between the muscle fibers and between adjacent muscles.* ***(Right)*** *Longitudinal ultrasound of the same patient shows the swollen semimembranosus muscle with largely intact muscle fibers. The appearances represent an infective pyomyositis. A small amount of fluid is tracking between the muscle fibers.*

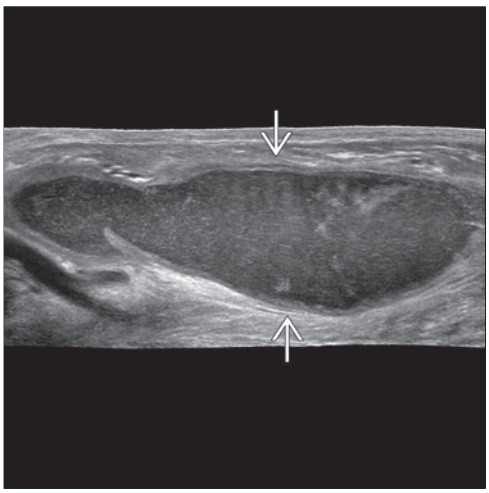


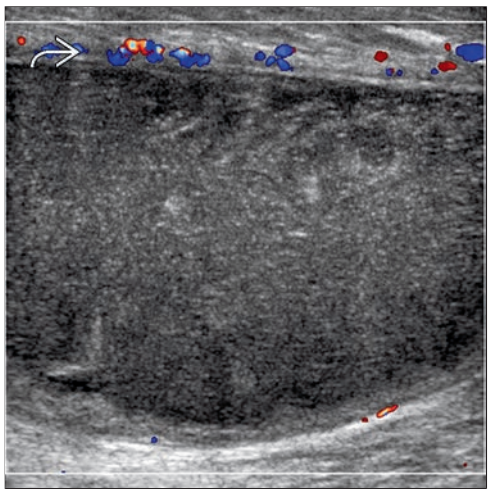




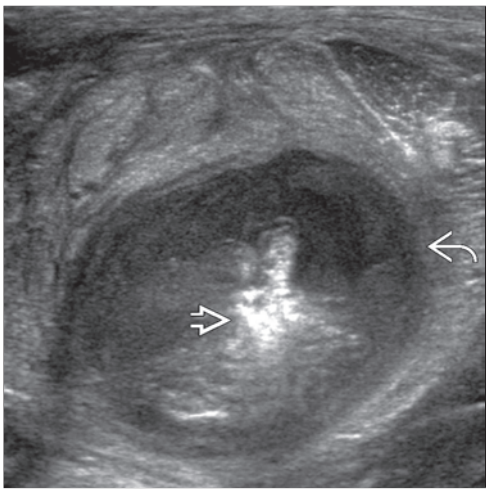


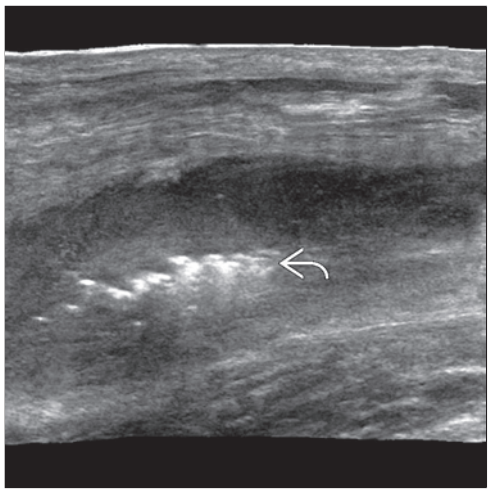
(Left) *Transverse ultrasound of the same patient 10 days later shows progressive myositis with loss of the normal fibrillary pattern. A small hypoechoic intramuscular focus due to early abscess formation is present.* ***(Right)*** *Transverse ultrasound of the same patient 4 days later shows evolving pyomyositis with an enlarged area of liquefaction due to abscess formation. Aspiration of the abscess yielded Stenotrophomonas maltophilia.*





(Left) *Extended field-of-view ultrasound in a patient with illicit intravenous drug use shows a large well-defined hypoechoic collection within the medial belly of the gastrocnemius. The well-defined thickened wall of the collection and the lack of surrounding soft tissue edema are indicative of a chronic abscess.* ***(Right)*** *Transverse color Doppler ultrasound of the same lesion shows mild to moderate hyperemia along the wall of the collection. Aspirate grew Staphylococcus aureus.*





(Left) *Transverse ultrasound of the thigh shows severe inflammation of the hamstring muscles with a large well-defined abscess within the semitendinosus muscle. The hyperechoic foci within the abscess are due to gas.* ***(Right)*** *Extended field-of-view ultrasound of the same patient shows multiple hyperechoic foci with "comet tail" artifact within this gas-forming abscess. Aspirate yielded Streptococcus milleri, Staphylococcus aureus, and Klebsiella species.*

BONE INFECTION

Key Facts

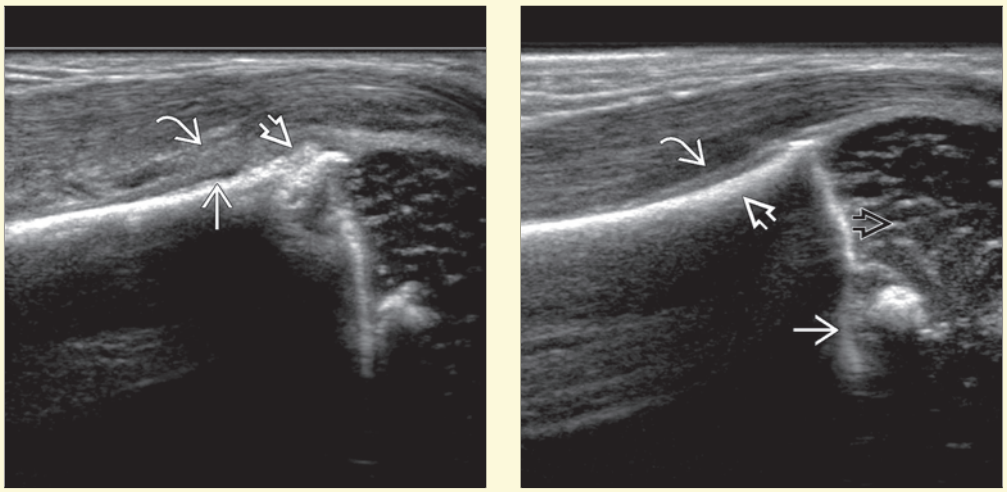
Imaging

- Periosteal thickening and hyperemia with juxtacortical edema
- Ultrasound can depict outer cortical, periosteal, and extraosseous changes
  - Periosteal thickening
  - ± juxtacortical soft tissue edema and hyperemia
  - ± cortical irregularity
  - ± sympathetic joint effusion
- Severe infection may show
  - Subperiosteal exudate, or less commonly, abscess
  - Soft tissue abscess
  - Cortical disruption ± extraosseous inflammatory mass
- Chronic osteomyelitis may show
  - Sinus tracts
  - Cloaca
  - Sequestra
- Ultrasound useful in neonates and young infants when clinical signs are often nonspecific
  - High propensity to develop periosteal reaction in children
  - Ultrasound shows features of acute osteomyelitis several days earlier than radiography
- Ultrasound useful in postoperative patients when metallic implants limit MR assessment
- Ultrasound useful in assessment of involvement of adjacent soft tissue and guiding aspiration or biopsy
- MR has highest sensitivity and specificity for both acute and chronic osteomyelitis

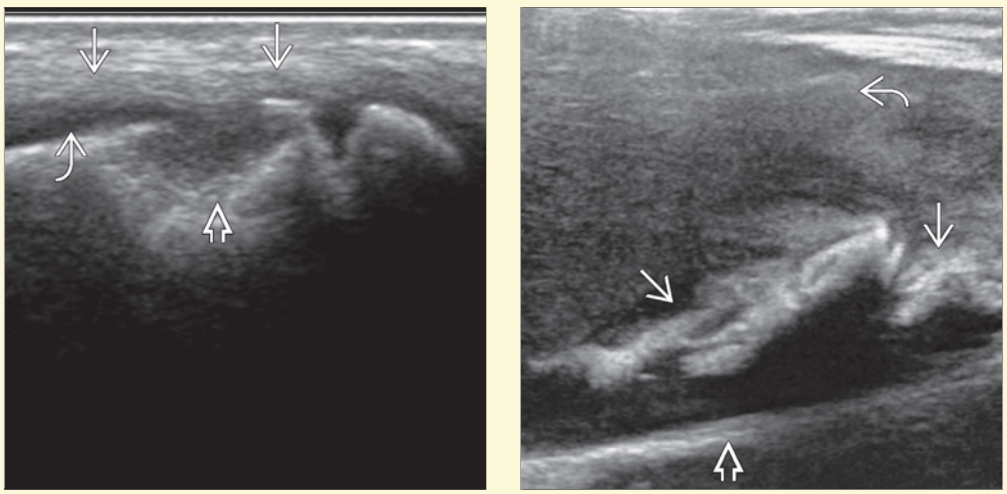
Top Differential Diagnoses

- Soft tissue infection
- Septic arthritis
- Bone sarcoma
- Leukemia or metastatic infiltration

(Left) *Longitudinal ultrasound of a neonate with acute osteomyelitis of the femur shows focal cortical irregularity at the distal femoral metaphysis. This is associated with periosteal soft tissue thickening and a small amount of subperiosteal fluid.* ***(Right)*** *Lateral ultrasound of the contralateral femur of the same patient shows the smooth cortex of the femoral metaphysis and normal thin hyperechoic periosteum. The physis and epiphysis are normal.*



(Left) *Longitudinal ultrasound shows acute osteomyelitis with a focal bone erosion filled by hypoechoic inflammatory soft tissue at the distal ulnar metaphysis with associated periosteal thickening and a small amount of subperiosteal exudate.* ***(Right)*** *Longitudinal ultrasound shows partially mineralized, thickened mature periosteal reaction deep to a large parosteal collection due to chronic osteomyelitis in the femoral diaphysis. The femoral bony cortex in this section is largely intact.*



BONE INFECTION

TERMINOLOGY

Definitions

- Osteomyelitis: Infection of bone marrow
- Acute osteomyelitis: Symptomatic osteomyelitis < 6 weeks duration
- Chronic osteomyelitis: Symptomatic osteomyelitis > 6 weeks duration
- Infective osteitis: Infection of bone cortex (usually contiguous with juxtacortical infection)
- Sequestrum (meaning "separated"): Fragment of dead bone surrounded by granulation tissue
- Involucrum (meaning "to wrap in"): Layer of living periosteal new bone formed around dead bone
- Cloaca (meaning "drain"): Opening in cortex or involucrum through which sequestra, fluid, or granulation tissue is discharged
- Brodie abscess: Focal area of chronic osteomyelitis with abscess and surrounding sclerosis

IMAGING

General Features

- Best diagnostic clue
  - Periosteal thickening and hyperemia with juxtacortical edema
- Location
  - Acute osteomyelitis: Metaphyses of long tubular bones
    - Metaphyses and epiphyses in infant
  - Chronic osteomyelitis: Diaphyses of long tubular bones
  - Osteitis: Alongside area of chronic soft tissue infection or ulceration
- Size
  - Acute osteomyelitis is usually less extensive than chronic osteomyelitis
- Morphology
  - Acute osteomyelitis: Bony resorption
  - Chronic osteomyelitis: Simultaneous bony resorption, draining infection (sequestra, cloaca, sinus tract), and bony repair (bone deposition, expansion)

Radiographic Findings

- Radiography
  - Insensitive for early acute osteomyelitis
    - Radiographic bony changes occur 10-14 days after symptom onset, depending on severity of infection
  - Sensitive for chronic osteomyelitis
    - Sclerosis, periosteal thickening, sequestra, cloaca, expansion ± bowing
    - Involucrum is rarely seen in modern practice

CT Findings

- NECT
  - Useful when MR is not available
  - Useful in chronic osteomyelitis for depicting cloaca, sequestra, and sinus tracts
    - Sequestra may be difficult to see on MR (hypointense) or radiography (if marked sclerosis and cortical thickening)
- CECT
  - Abscesses and sinus tracts enhance peripherally

MR Findings

- T1WI
  - Hypointense marrow edema ± cortical destruction
- T2WI FS
  - Acute osteomyelitis: Hyperintense marrow edema without discrete mass
    - ± focal cortical destruction, ± periosteal thickening (lamellar, Codman triangle)
    - ± juxtacortical edema, inflammation, or inflammatory mass
    - MR = highly sensitive and specific for acute osteomyelitis
  - Chronic osteomyelitis; additional findings include
    - ± intraosseous, transcortical, or extraosseous sinus tracts
    - ± hypointense sequestra
    - ± periosteal thickening (from lamellar immature to thick mature)
    - Appearances vary with level of inflammatory activity
  - Brodie abscess (intramedullary abscess cavity): Hyperintense + hypointense sclerotic rim
    - Abscess surrounded by reactive sclerotic bone and inflammation
- T1WI C+
  - Differentiates abscess (rim enhancement) from inflammatory tissue (diffuse enhancement)
    - Sequestra, in chronic osteomyelitis, may also enhance peripherally and simulate abscess
    - Enhancing tissue in chronic osteomyelitis may represent reparative or inflammatory tissue

Ultrasonographic Findings

- Ultrasound useful in neonates and young infants when clinical signs are often nonspecific
  - Shows features of acute osteomyelitis several days earlier than radiography
  - Less sensitive than MR or scintigraphy
- Ultrasound sensitivity is highest in suspected osteomyelitis of tubular bones in children where propensity to develop periosteal reaction is highest
- Ultrasound also useful in postoperative patients when metallic implants limit MR assessment
- Ultrasound usually only depicts outer cortical, periosteal, and extraosseous changes
  - Periosteal thickening is seen as periosteal hyperemic rim, usually with hyperemia
  - ± juxtacortical soft tissue edema and hyperemia
  - ± cortical irregularity
  - ± sympathetic joint effusion
- Severe infection may show
  - Subperiosteal exudate, or less commonly, abscess
  - Soft tissue abscess
    - Amenable to ultrasound-guided aspiration
  - Cortical disruption ± extraosseous inflammatory mass
    - Amenable to ultrasound-guided biopsy
    - Visualization of medullary canal if osteolysis of overlying cortex provides acoustic window
- Chronic osteomyelitis may show
  - Sinus tracts
  - Cloaca
  - Sequestra

BONE INFECTION

- Ultrasound appearances of acute bone infection are nonspecific
  - Periosteal thickening ± subperiosteal fluid ± soft tissue edema also seen in
    - Stress reaction of bone
    - Sickle cell disease with medullary infarction
    - Bone sarcoma
- In neonates and young children, pure chondral infection may occur
  - May be difficult to detect on ultrasound as hypoechoic fluid is of similar echogenicity to hypoechoic cartilage

Nuclear Medicine Findings
- Increased tracer activity in the 3-phase bone scan, gallium scan, WBC scan, and PET/CT

Imaging Recommendations
- Best imaging tool
  - MR: High sensitivity and specificity for both acute and chronic osteomyelitis
    - Very high negative predictive value, i.e., normal MR excludes osteomyelitis
  - US: Assess involvement of adjacent soft tissue
    - Guide aspiration or biopsy for histology, microbiology, and treatment
    - Useful in regions with orthopedic instrumentation where infection might not be seen by MR or CT
    - Useful in assessment of soft tissue involvement, especially in chronic osteomyelitis
- Protocol advice
  - In acute osteomyelitis, periosteal reaction is most specific sign
    - Proceed to MR if ultrasound is positive and also if ultrasound is negative and there is strong clinical suspicion of osteomyelitis
  - Check for signs of osteomyelitis if performing ultrasound for suspected soft tissue or joint infection

DIFFERENTIAL DIAGNOSIS

Soft Tissue Infection
- Soft tissue edema and inflammation ± inflammatory mass ± abscess
- Check bone surface for signs of osteomyelitis

Septic Arthritis
- Similar clinical picture to acute osteomyelitis
- Medium to large joint effusion ± hyperemia ± positive joint aspiration

Bone Sarcoma
- No clinical signs of infection
- Cortical destruction ± extraosseous soft tissue mass ± spiculated new bone formation

Leukemia or Metastatic Infiltration
- Usually known primary tumor
- Multiple sites of involvement in leukemia

PATHOLOGY

General Features
- Etiology
  - *Staphylococcus aureus*: Most common infecting organism in all age groups
  - Common organisms: *Streptococcus*, *Pseudomonas*, *Haemophilus*, *Enterobacter*, *Mycobacterium*
  - May be due to mixed organisms
    - Especially chronic osteomyelitis

Gross Pathologic & Surgical Features
- Hematogenous seeding
- Direct contamination

Microscopic Features
- Inflammation of marrow
- Vascular compromise
- Necrosis, abscesses, sequestra

CLINICAL ISSUES

Presentation
- Most common signs/symptoms
  - Pain, tenderness, fever with signs of inflammation
- Other signs/symptoms
  - Restricted motion, constitutional symptoms
- Clinical profile
  - Acute osteomyelitis progresses over days to weeks
    - ± positive blood cultures
  - Chronic osteomyelitis usually presents de novo without preexisting acute osteomyelitis
    - Typically established at time of presentation
    - Early disease is subclinical

Demographics
- Age
  - Acute osteomyelitis more common in young children
  - Chronic osteomyelitis more common in older age group
- Epidemiology
  - Both acute and chronic osteomyelitis less common with increasing economic development globally
  - Chronic osteomyelitis in adults usually 2° to trauma

Natural History & Prognosis
- Good prognosis for acute osteomyelitis if treated early
- Chronic osteomyelitis is difficult to fully eradicate; relapsing-remitting clinical course

Treatment
- Conservative
  - Rest, elevation, intravenous antibiotics
- Surgical
  - Debridement ± antibiotic-impregnated beads

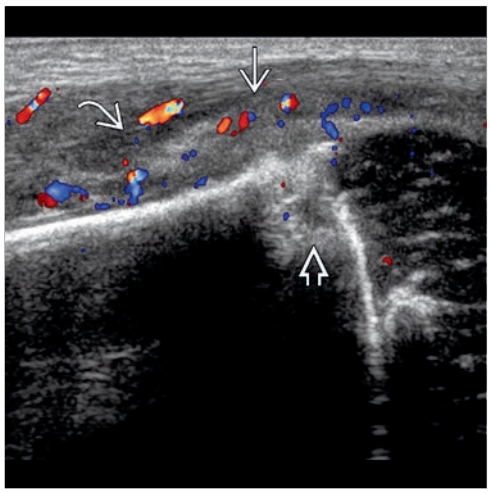
DIAGNOSTIC CHECKLIST

Consider
- Bone infection if unexplained periosteal thickening or juxtacortical inflammatory mass is detected even though cortex seems intact

SELECTED REFERENCES

1. van Schuppen J et al: Childhood osteomyelitis: imaging characteristics. Insights Imaging. 3(5):519-33, 2012



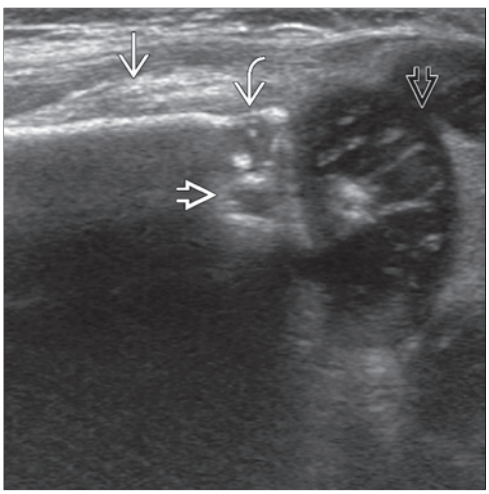


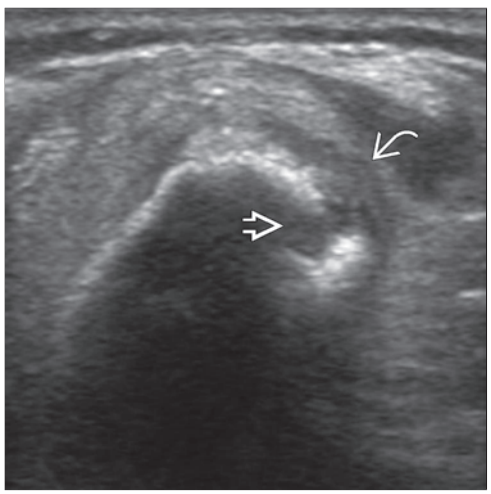
(Left) *Frontal radiograph of a 13-day-old neonate with fever and decreased leg movement shows mild cortical resorption at the distal femoral metaphysis, with a fine periosteal reaction. **(Right)** Longitudinal color Doppler ultrasound of the same patient shows acute osteomyelitis with focal metaphyseal cortical resorption, moderate periosteal soft tissue thickening, and hyperemia. A small amount of fluid is present alongside the periosteal soft tissue.*





(Left) *Frontal radiograph of the same patient 5 days later shows progressive osteolysis and periosteal reaction consistent with acute osteomyelitis. **(Right)** Sagittal STIR MR of the same patient shows metaphyseal marrow edema with thickened, hyperintense inflamed periosteal soft tissue consistent with acute osteomyelitis.*



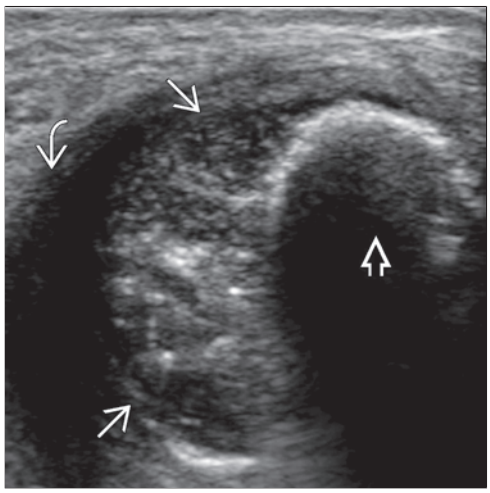


(Left) *Longitudinal ultrasound of a neonate with acute osteomyelitis shows focal cortical resorption at the distal femoral metaphysis and a hypoechoic area in the adjacent medullary cavity. The hypoechoic epiphysis is normal with early ossification. The metaphyseal periosteum is thickened. **(Right)** Transverse ultrasound of the same patient shows a focal cortical femoral defect with overlying edematous, hypoechoic inflammatory tissue.*

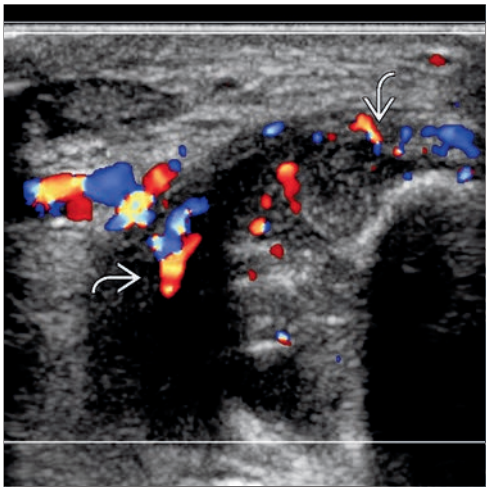
BONE INFECTION

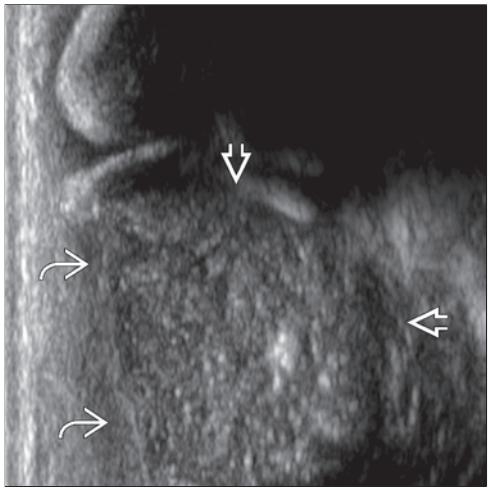
(Left) *Frontal radiograph of a 14-year-old who presented with fever and wrist pain shows a lytic lesion with a wide zone of transition in the distal ulnar metaphysis.* ***(Right)*** *Transverse ultrasound of the same patient shows prominent solid-appearing juxtacortical soft tissue thickening surrounding the distal ulna. Echogenic seams represent new bone formation. An outer hypoechoic area representing fluid or severe edema is present.*



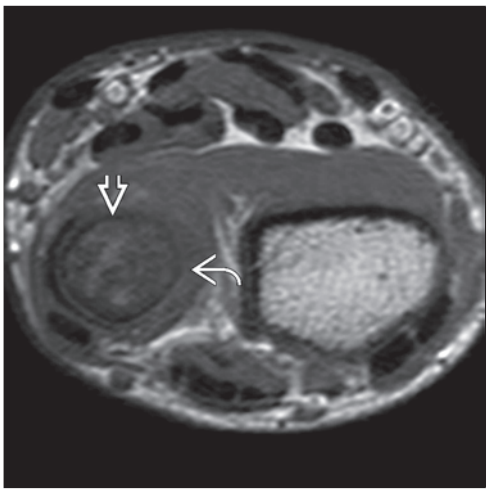


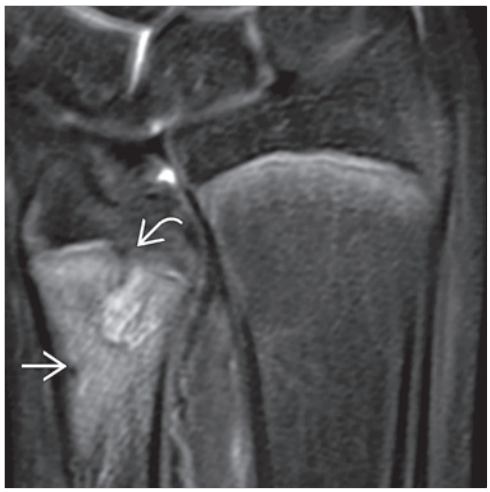
(Left) *Transverse color Doppler ultrasound of the same patient shows moderate to severe hyperemia in the juxtacortical soft tissues. Overall appearances favor either bone sarcoma or infection.* ***(Right)*** *Longitudinal ultrasound of the same patient shows an osteolytic area filled by heterogeneous inflammatory soft tissue in the distal ulnar metaphysis. The normal hyperechoic outer cortex is lost.*

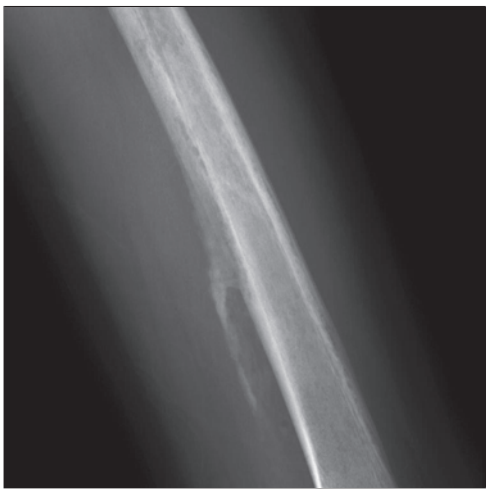


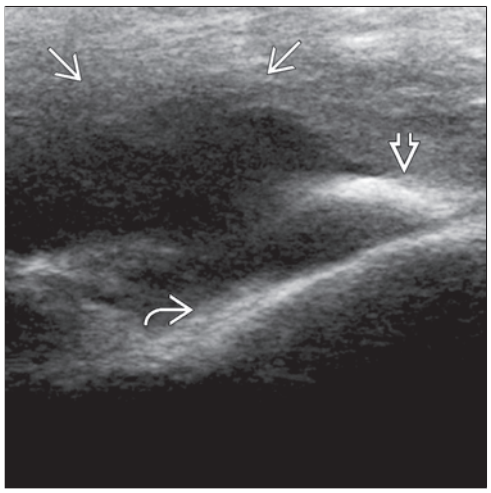


(Left) *Axial T1 MR of the same patient shows a loss of normal fatty marrow signal in the distal ulnar metaphysis with a surrounding thick rind of hypointense soft tissue.* ***(Right)*** *Coronal T2FS MR shows moderate marrow edema at the distal ulnar metaphysis with involvement of the physis. MR is better than US in depicting physeal or transphyseal involvement. Percutaneous biopsy confirmed acute osteomyelitis.*

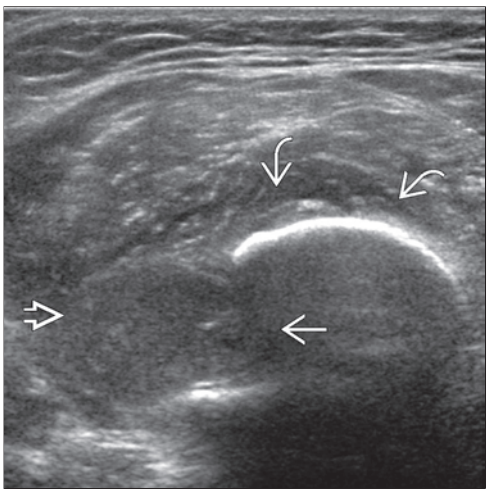


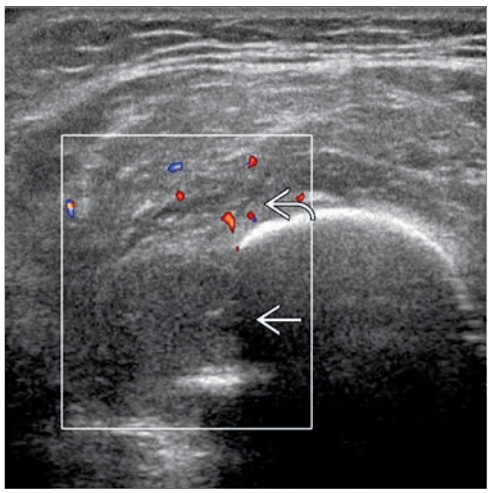




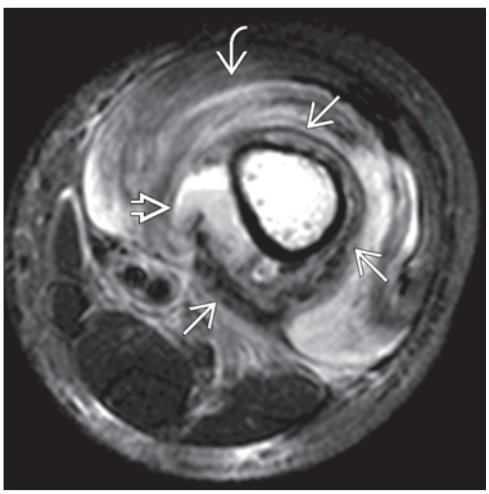


(Left) *Lateral radiograph of an 11-year-old patient with subacute thigh pain shows mild diffuse osteosclerosis with irregular mature-type periosteal thickening along the femoral diaphysis posteriorly.* ***(Right)*** *Longitudinal ultrasound of the same patient shows a hypoechoic extraosseous collection extending deep to the thickened, ossified periosteal tissue on the posterior femoral cortex, indicative of a subacute exacerbation of chronic osteomyelitis.*





(Left) *Transverse ultrasound of the same patient shows mild periosteal thickening anteriorly with a hypoechoic collection adjacent to a focal cortical defect in the posterolateral cortex (cloaca).* ***(Right)*** *Transverse color Doppler ultrasound in the same patient shows only mild juxtacortical hyperemia and soft tissue thickening indicative of moderate severity active inflammation. The hypoechoic collection demonstrates no intrinsic vascularity.*

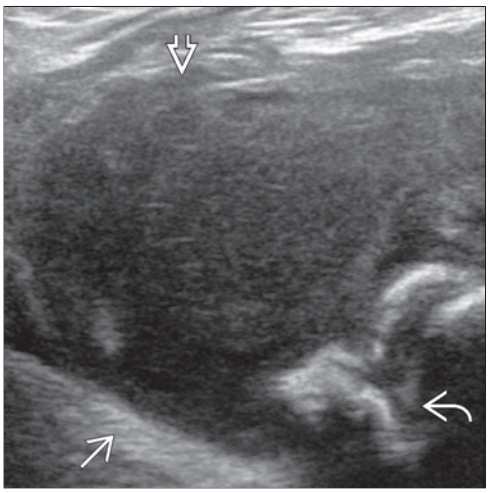


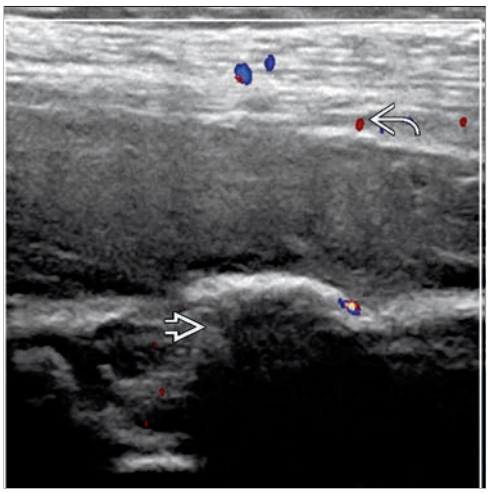


(Left) *Axial T2WI FS MR of the same patient shows a hyperintense fluid-rich bone marrow with a hypointense thickened periosteum due to ossification (involucrum). A subperiosteal collection with a fluid level is present associated with this subacute infection. There is severe quadriceps muscle edema.* ***(Right)*** *Three-phase bone scintigraphy in the same patient shows mild increased tracer accumulation in the femoral shaft. Additional imaging showed mild increased perfusion and blood pool activity in this region.*

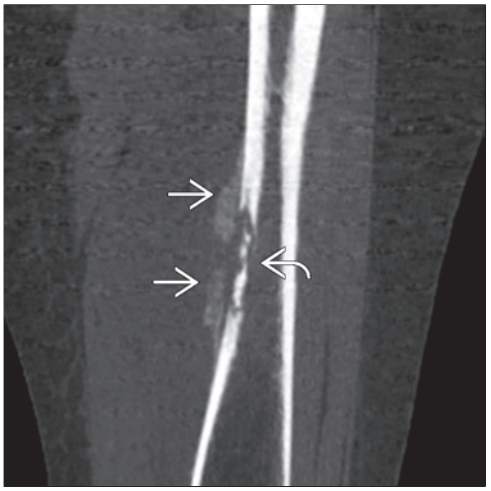
BONE INFECTION

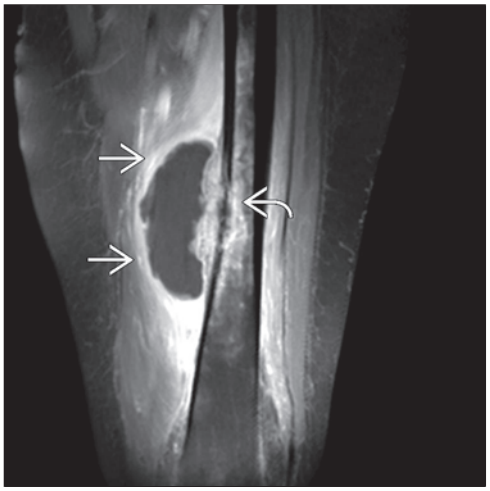
(Left) *Transverse ultrasound of an adult with acute fever and subacute thigh pain shows a large hypoechoic collection alongside the femoral diaphyseal cortex associated with a thickened ossified periosteal reaction.* ***(Right)*** *Longitudinal ultrasound of the same patient shows minimal hyperemia in the adjacent soft tissues. The ossified periosteal new bone leads to strong acoustic shadowing.*



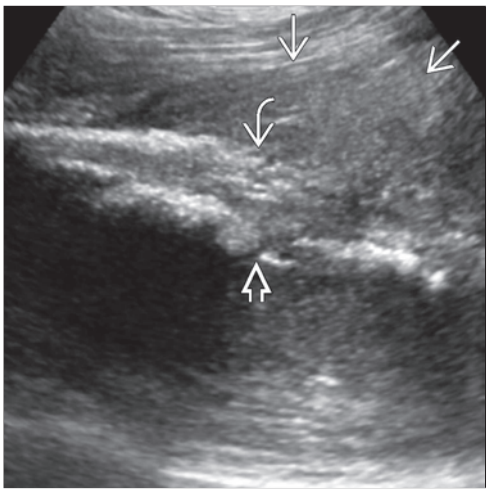


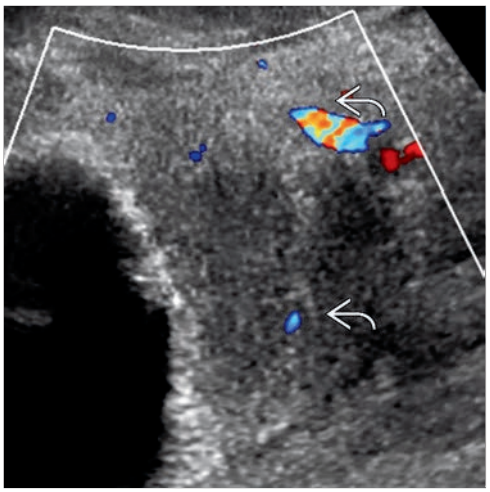
(Left) *NECT with coronal reformat of the same patient shows focal femoral cortical osteolysis associated with ossified periosteal thickening.* ***(Right)*** *Coronal T1 C+ FS MR of the same patient shows enhancing inflammatory tissue near the cortical osteolysis. The severe inflammation around the large parosteal fluid collection is consistent with an abscess. This is aspirated under ultrasound guidance. Culture grew Streptococcus milleri. Final diagnosis is juxtacortical abscess with established osteitis and early osteomyelitis.*

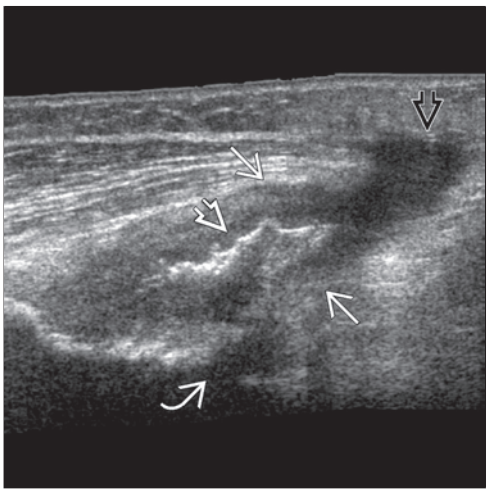


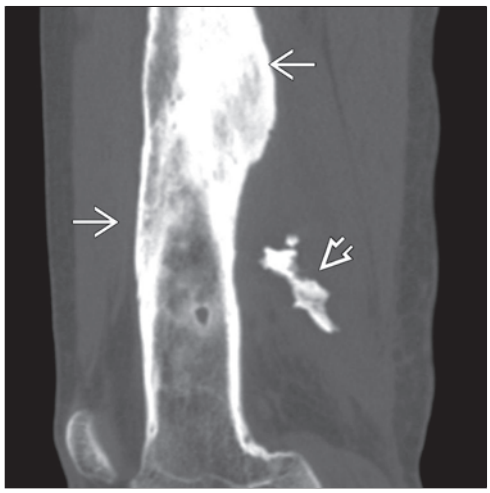


(Left) *Longitudinal ultrasound of an adult with thigh pain shows focal cortical disruption in the femoral diaphysis with a lamellar periosteal reaction and a large extraosseous inflammatory mass, consistent with an acute exacerbation of chronic osteomyelitis.* ***(Right)*** *Transverse color Doppler ultrasound of the same patient shows hyperemia of the inflammatory mass. Ultrasound-guided biopsy grew Klebsiella while histology revealed acute on chronic inflammation.*

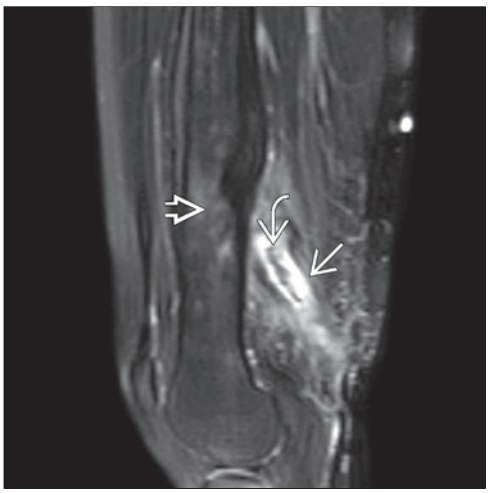


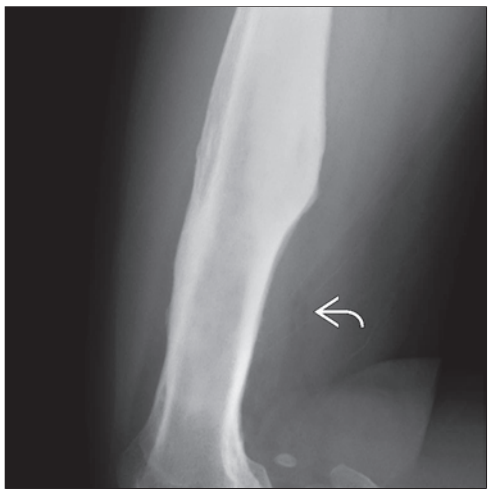




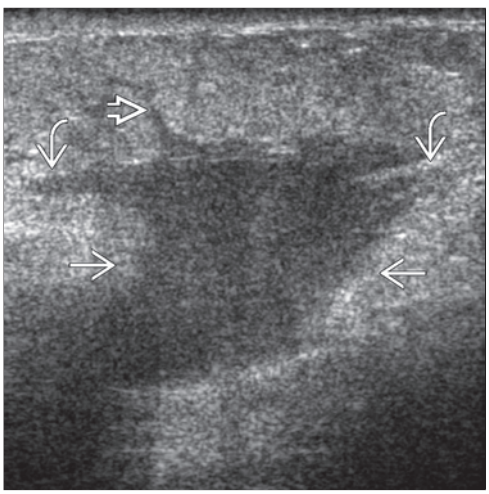


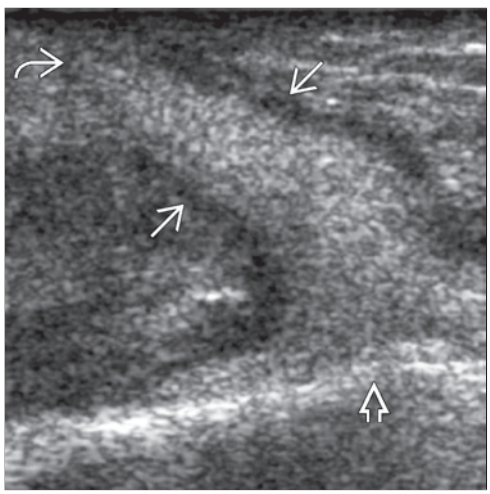
(Left) *Longitudinal ultrasound with extended field of view shows a large sequestrum within a sinus tract extending from an irregular femoral cortex to the investing fascia of the thigh. **(Right)** Longitudinal NECT with sagittal reconstruction of the same patient shows the sequestrum and a severely thickened sclerotic femoral diaphysis, all indicative of chronic osteomyelitis.*





(Left) *Sagittal STIR MR of the same patient shows a hypointense sequestrum with surrounding hyperintense inflamed granulation tissue within a thin sinus tract. Mild medullary canal edema and extraosseous soft tissue indicate low-grade chronic inflammation. **(Right)** Lateral radiograph of the femur in the same patient following sequestrectomy and debridement shows clearance of the sequestrum.*

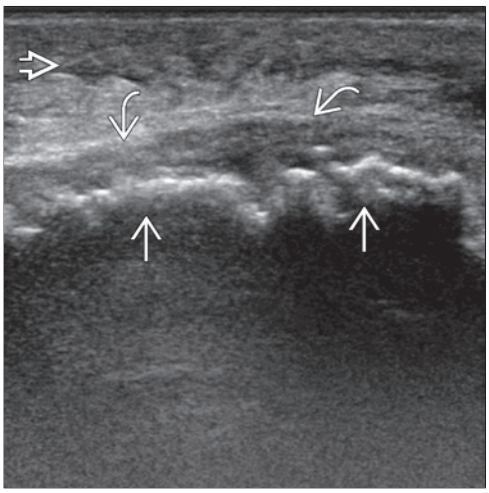


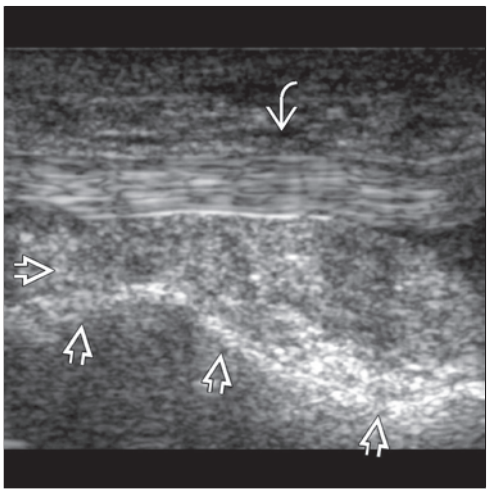


(Left) *Longitudinal ultrasound shows an immature sinus tract extending superficially from the bone (not shown) with discontinuity of the investing fascia and permeations along the fascia and into the subcutaneous fat. Such permeation is indicative of infection. **(Right)** Longitudinal ultrasound shows a mature sinus tract lined by hypoechoic fibrotic tissue extending from the bone cortex to the skin in chronic osteomyelitis. Note how the point of contact with the cortex is intact on ultrasound.*

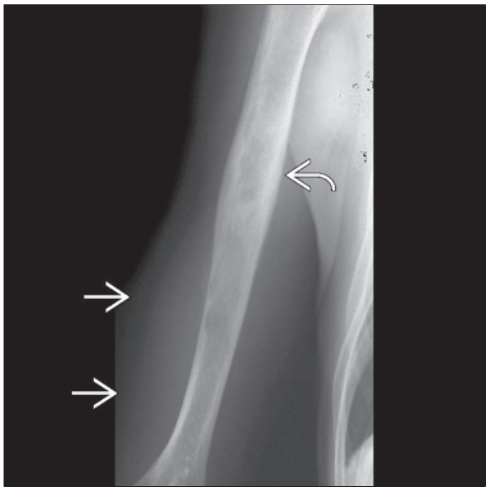
BONE INFECTION

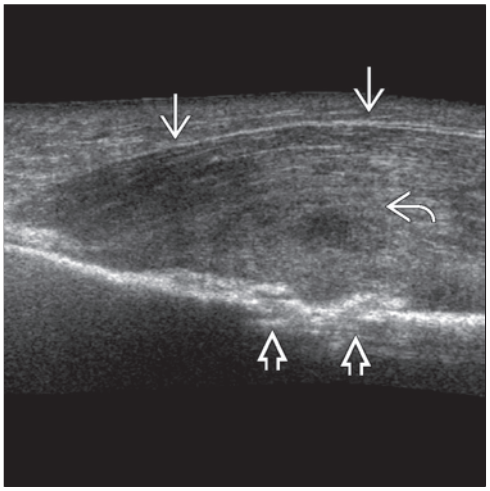
(Left) *Transverse ultrasound in a patient with post-traumatic chronic osteomyelitis shows diffuse cortical irregularity of the distal tibia with moderate immature periosteal thickening and subcutaneous soft tissue edema.* ***(Right)*** *Longitudinal ultrasound of a patient with acute exacerbation of chronic distal tibial osteomyelitis shows severe immature periosteal thickening. The posterior tibialis tendon is normal.*



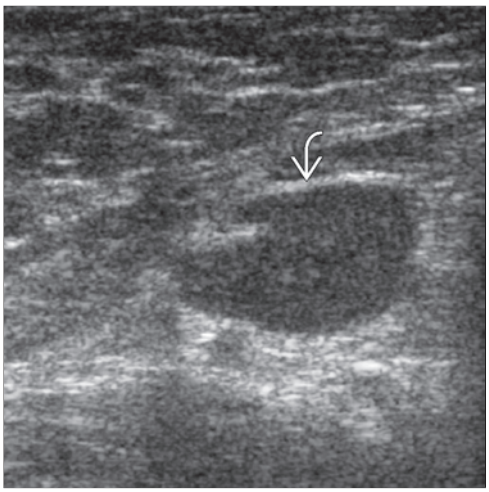


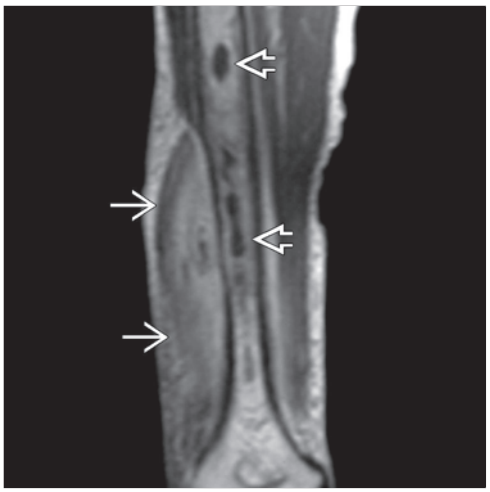
(Left) *Frontal radiograph shows mild expansion, mixed sclerosis, and lysis of the midhumeral diaphysis with soft tissue thickening distally. The radiographic appearances are suggestive of sarcoma or chronic osteomyelitis.* ***(Right)*** *Longitudinal ultrasound of the same arm shows focal cortical disruption of the mid humeral diaphysis, a large extramedullary inflammatory-type mass with a small cystic area indicative of acute exacerbation of chronic osteomyelitis.*

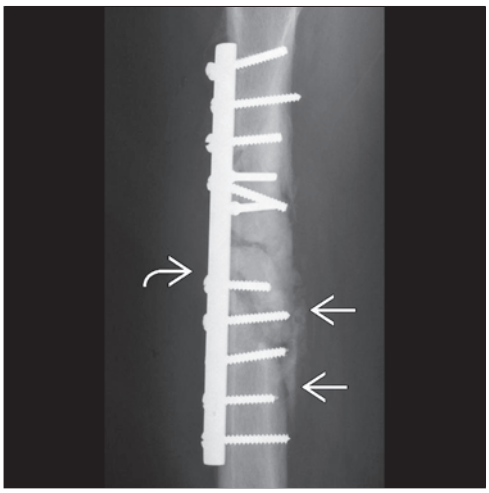


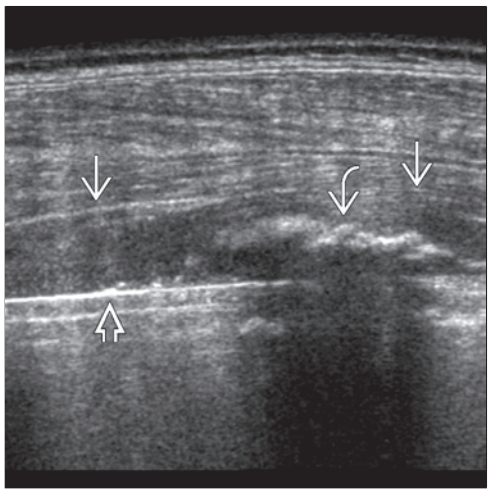


(Left) *Transverse ultrasound of the same patient shows the small, cystic-type area within the inflammatory mass. Ultrasound-guided aspiration yielded purulent fluid, which grew Staphylococcus aureus.* ***(Right)*** *Longitudinal T1 C+ MR in the same patient shows several small intramedullary abscesses with a large juxtacortical inflammatory mass distally compatible with acute exacerbation of chronic osteomyelitis*

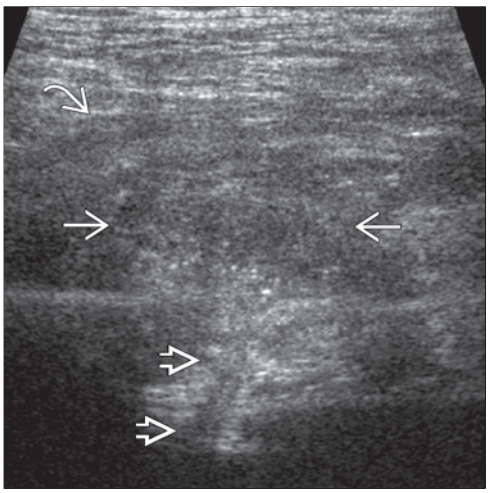


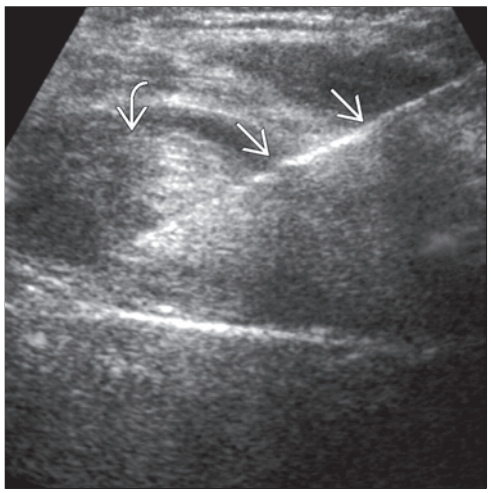




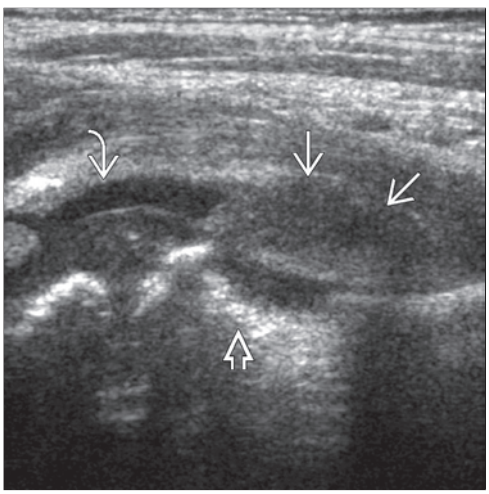


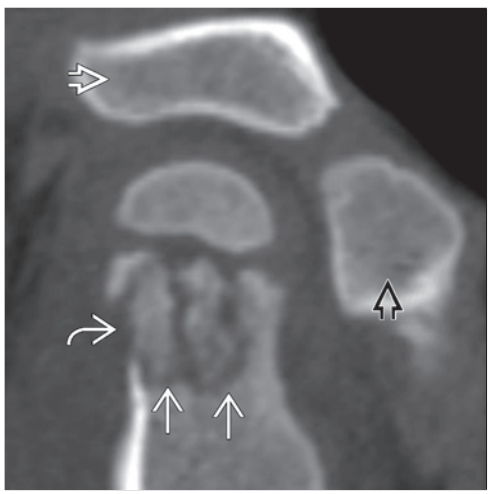
(Left) *Radiograph shows a nonunited fracture of the femoral shaft with plate and screw fixation. There is a mature, interrupted lamellar periosteal new bone suggestive of osteomyelitis.* ***(Right)*** *Extended field of view ultrasound of the same patient shows inflammatory-type tissue alongside the fixation plate and periosteal new bone formation, all consistent with postoperative chronic osteomyelitis.*





(Left) *Longitudinal ultrasound of the same patient shows inflammatory exudate exuding from the fracture site. More generalized edema of the juxtacortical tissue is present.* ***(Right)*** *Longitudinal ultrasound in the same patient shows a percutaneous core biopsy of inflammatory tissue. Culture yielded Staphylococcus aureus. Histology revealed acute on chronic inflammation.*





(Left) *Lateral ultrasound shows marked synovial thickening of the hip joint, a small effusion, and a large cortical defect on the anterolateral aspect of the proximal femoral metaphysis. Percutaneous biopsy revealed tuberculous infection.* ***(Right)*** *CECT of the proximal femur in the same patient shows an anterior cortical defect and intramedullary channel-like defects in the femoral metaphysis indicative of infection (tuberculous osteomyelitis). The iliac and ischial portions of the acetabulum are normal.*

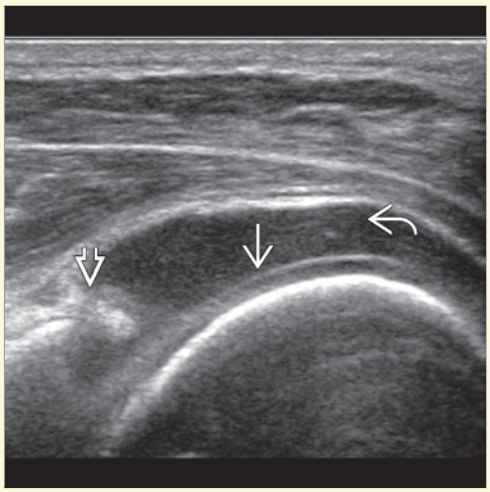
JOINT INFECTION

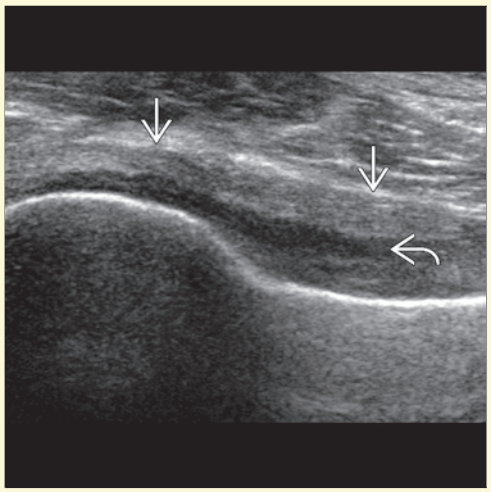
Key Facts

Imaging

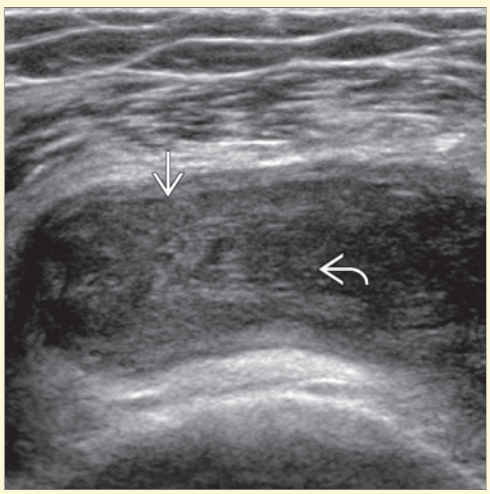
- Echogenic joint effusion with positive aspirate ± synovial/capsular thickening and hyperemia
- Normal US examination excludes septic arthritis provided joint well seen
- **Joint effusion** is cardinal sign of septic arthritis
  - ± fine echoes within joint fluid ± swirling or moving echoes on real-time imaging
  - Effusion is minimal in poorly distensible joints (e.g., acromioclavicular, sternoclavicular, sacroiliac joints)
- Synovial/capsular thickening
  - Chronic infection in prosthetic joints may comprise only synovial/capsular thickening
- Bone and cartilage change
  - Progressive joint space narrowing (chondrolysis)
  - Marginal erosion (osteolysis)
  - Secondary degenerative change
  - Features of osteomyelitis
- Periarticular soft tissue extension
- ± visible capsular rupture
  - ± pericapsular inflammatory mass
  - ± pericapsular abscess
- As chronicity of infection increases
  - Amount of effusion decreases
  - Degree of synovial proliferation increases
  - Degree of bone and cartilage damage increases
- Ultrasound appearances of infective arthritis and noninfective inflammatory arthritis overlap considerably
  - Patients with inflammatory arthropathy, osteoarthritis, and joint prosthesis more prone to infection
- Joint aspiration and analysis of joint fluid best way to exclude joint infection or US-guided synovial biopsy if little or no joint fluid in, for example, suspected prosthetic joint infection

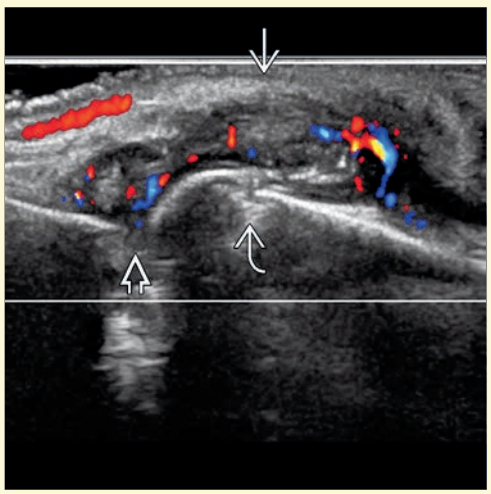
(Left) *Longitudinal ultrasound shows a moderate glenohumeral effusion without synovial proliferation due to acute septic arthritis (Salmonella enteritidis). Note the clear visualization of cartilage and posterior glenoid labrum.* ***(Right)*** *Longitudinal ultrasound of the hip shows moderate synovial proliferation with a small effusion in a patient with juvenile rheumatoid arthritis. This may be due to either infective or inflammatory arthritis. Joint aspirate yielded Moraxella species.*





(Left) *Transverse ultrasound of the knee shows a small effusion at the suprapatellar pouch with severe synovial proliferation due to chronic joint infection with Staphylococcus aureus.* ***(Right)*** *Longitudinal color Doppler ultrasound shows moderately hyperemic synovial proliferation on the dorsum of the index metacarpophalangeal joint. There is a small erosion of the 2nd metacarpal neck. This arthritis was due to tuberculosis confirmed by histology and microbiology following surgical exploration.*





JOINT INFECTION

TERMINOLOGY

Synonyms
- Infective arthritis, septic arthritis

Definitions
- Infection of joint

IMAGING

General Features
- Best diagnostic clue
  - Echogenic joint effusion with positive aspirate ± synovial/capsular thickening and hyperemia
- Location
  - Any joint can potentially be infected
    - Knee > hip > shoulder > wrist
      - More common in synovial joints as usually blood-borne infection
    - May be multifocal, especially in at-risk patients
    - Gonococcal arthritis: Predilection for small joints of hands and feet (disseminated gonococcal infection)

Radiographic Findings
- Radiography
  - Early stages
    - Usually normal
    - ± joint effusion, widening of affected joint
    - ± periarticular swelling and obliteration of fat planes
    - ± periarticular osteopenia due to hyperemia
  - Late stages
    - ± narrowing of joint space (chondrolysis), marginal erosions (osteolysis), secondary osteoarthrosis, ankylosis

MR Findings
- T1WI
  - Hypointense or isointense joint effusion
  - ± hypointense periarticular marrow edema
  - ± hypointense paraarticular soft tissue extension
- T2WI
  - Hyperintense joint effusion with capsular distension
    - ± synovial proliferation
    - ± periarticular edema, inflammation, or abscess
- T1WI C+
  - Enhancement of synovium, capsule, pericapsular tissues

Ultrasonographic Findings
- Normal ultrasound examination excludes septic arthritis provided joint well seen
- **Joint effusion**
  - Cardinal sign of septic arthritis
  - ± clumps of echoes or multiple fine echoes within joint fluid
    - Swirling or moving echoes on real-time imaging
  - Anechoic joint fluid does not exclude septic arthritis
    - Joint aspiration and analysis of joint fluid is only way to truly exclude joint infection
  - In some nondistensible joints (e.g., acromioclavicular, sternoclavicular, sacroiliac joints), effusion is minimal
  - Amount of joint fluid decreases as chronicity of infection increases
  - Viscosity of joint fluid increases as chronicity of infection increases
- **Synovial/capsular thickening**
  - Synovial proliferation and capsular thickening increase as chronicity of infection increases
    - Chronic infection in prosthetic joints may comprise only synovial/capsular thickening
  - ± hyperemia
    - Degree of hyperemia correlates with degree of active inflammation
  - Prominent synovial/capsular thickening and hyperemia in nondistensible joints
- **Bone and cartilage change**
  - Seen in subacute or later phase of infection
  - Progressive joint space narrowing (chondrolysis)
  - Marginal erosions (osteolysis)
  - Secondary degenerative change
  - Features of osteomyelitis
- **Periarticular soft tissue extension**
  - ± visible capsular rupture
  - ± pericapsular inflammatory mass
  - ± pericapsular abscess

Imaging Recommendations
- Best imaging tool
  - Ultrasound, as nearly all joints are accessible to ultrasound examination
    - No metallic artifact from joint prosthesis
- Protocol advice
  - Ultrasound-guided aspiration for cytology, culture, and crystals (adults)
    - Prior to initiation of antibiotic therapy
  - Cytology: Turbid, low-viscosity fluid with leucocyte count > 50,000 per mm^3
    - ~ 90% polymorphs
  - Crystal: Compensated polarized light microscopy sample should be fresh (i.e., not mixed with water or alcohol, as these will dissolve crystals)
    - Uric acid crystals (negatively birefringent)
    - Calcium pyrophosphate dihydrate crystals (positively birefringent)
    - Simultaneous crystalline and bacterial arthritis may occur
  - Gram stain and culture
    - Send sample for culture stat
    - Higher yield than if sample is left standing or kept in refrigerator overnight
    - Aerobic, anaerobic, mycobacterial, and fungal cultures
    - Aspirate Gram stain is positive in 50% of infective arthritis
    - Aspirate culture is positive in 90% of infective arthritis
  - Ultrasound-guided synovial biopsy
    - Tru-Cut core biopsy

DIFFERENTIAL DIAGNOSIS

Transient Synovitis of the Hip
- Predominantly occurs in children
- Self limiting

JOINT INFECTION

- Anechoic or mildly echogenic fluid ± synovial/capsular thickening
  - Often subclinical synovitis of contralateral hip

Crystal Arthropathy
- Synovitis ± effusion ± crystalline particles (seen as "comet tail" artifacts)
  - ± periarticular tophi, ± elevated serum uric acid

Hemarthrosis
- Traumatic or spontaneous onset ± underlying coagulopathy
- Finely echogenic fluid is similar to acute septic arthritis
  - Synovial/capsular thickening is not an acute feature

PATHOLOGY

General Features
- Etiology
  - Most commonly due to hematogenous seeding of synovium from bacteremia
  - Less common causes
    - Surgery (arthroplasty), spread from adjacent osteomyelitis, inoculation during needling, penetrating trauma
- Organisms
  - *Staphylococcus aureus*
    - Most common organism, especially in diabetics and rheumatoid arthritis patients
    - Late (> 3 months) infection of prosthesis
    - Early infection of prosthesis related to surgical contamination, and is more commonly due to *Staphylococcus epidermidis*
  - *Streptococcus pyogenes*
  - Gram-negative organisms (*Pseudomonas aeruginosa*, *Escherichia coli*, *Neisseria gonorrhoeae*)
    - Especially intravenous (IV) drug users, extremes of age, and immunosuppressed patient
    - *Neisseria gonorrhoeae* may lead to disseminated gonococcal infection
    - Gonococcal infection also causes reactive arthritis

Gross Pathologic & Surgical Features
- No limiting basement plate under well-vascularized synovium; facilitates bacterial entry to joint
  - → bacterial adherence and colonization
  - → bacterial proliferation → acute inflammatory response
  - → cytokine and acute phase protein release → tissue damage

CLINICAL ISSUES

Presentation
- Most common signs/symptoms
  - Monoarticular pain, swelling, and limitation of movement
- Other signs/symptoms
  - Fever, malaise
- Clinical profile
  - At-risk patients with recent onset of joint inflammation

Demographics
- Age
  - Extremes of age, especially elderly
- Gender
  - Nongonococcal arthritis: M:F = 1:1
  - Gonococcal arthritis: M:F= 1:10
- Epidemiology
  - Incidence: 2-10 per 100,000 per year
  - More common in the following groups of patients
    - Patients over 60 years old
      - Due to higher prevalence of degenerative joint disease and reduced immunity
    - Patients with rheumatoid arthritis (10x more common than general population)
    - Patients with diabetes, poor general health, long-term corticosteroid usage
    - Patients with joint prosthesis

Natural History & Prognosis
- Depends on immunocompetency of host, virulence of organism, rapidity of detection, treatment response
  - Nongonococcal septic arthritis: Prognosis is good if detected and treated early
    - Early: ≤ 7 days after onset of symptoms
  - Poor prognostic indicators
    - > 6 days to make joint (clinically) sterile after onset of treatment
    - Virulent organism
    - Elderly
    - Immunosuppressed
- Morbidity: 5-20% due to bacteremia
  - Septic oligoarthritis (30% mortality)
  - Septic oligoarthritis + rheumatoid arthritis or *Staphylococcus aureus* infection = 50% mortality
- Gonococcal septic arthritis: Good prognosis
  - Symptoms ↓ rapidly without sequelae

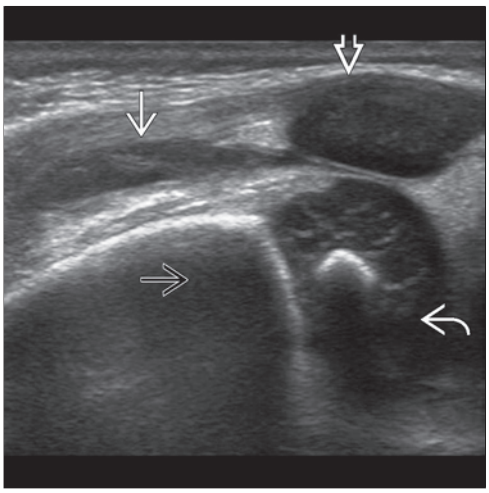
Treatment
- Conservative
  - IV antibiotics
  - Splinting to prevent contractures
  - ± repeated ultrasound-guided percutaneous aspiration
  - ± percutaneous ultrasound-guided tidal irrigation
    - Irrigation of joint through closed system
  - Physiotherapy once symptoms improve
- Arthrotomy or arthroscopic debridement and wound irrigation
- Infected prosthesis usually requires replacement
  - Removal and debridement (stage 1)
  - Reimplantation (stage 2)

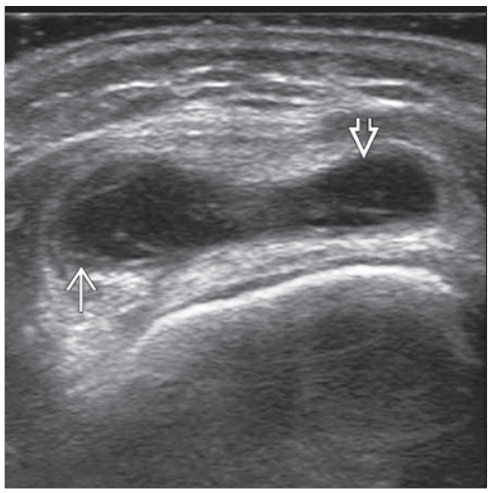
DIAGNOSTIC CHECKLIST

Consider
- Ultimate diagnosis rests on isolating pathogens from aspirated joint fluid
  - Early diagnosis and treatment is key to success
- Normal ultrasound examination excludes septic arthritis
- Ultrasound and aspiration establishes diagnosis; MR assesses damage

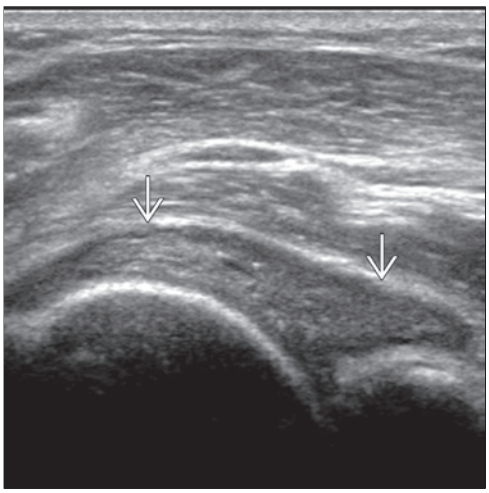
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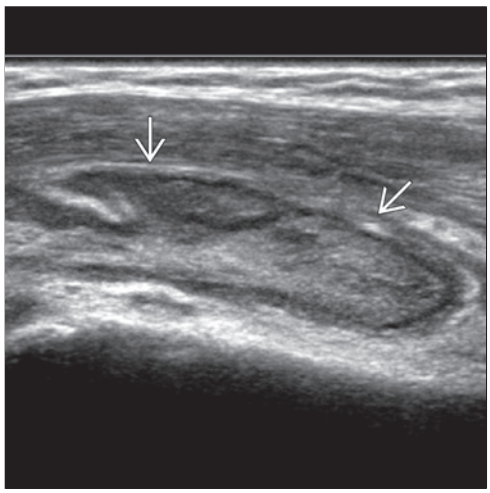
1. Pääkkönen M et al: Bone and joint infections. Pediatr Clin North Am. 60(2):425-36, 2013



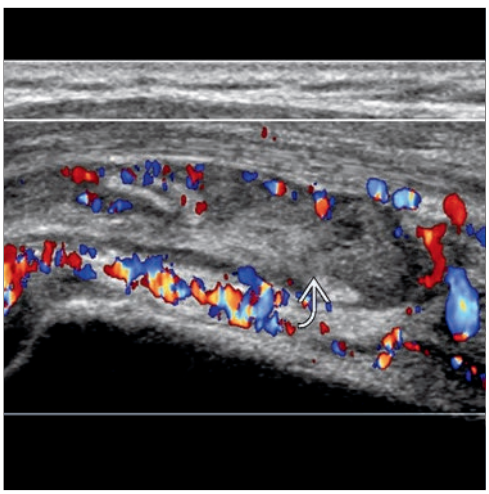


(Left) *Longitudinal ultrasound of a neonate with fever and knee swelling shows a small joint effusion* ➔ *in the suprapatellar recess. The patella* ➔, *distal femoral metaphysis* ⇨, *and epiphysis* ➔ *are normal.* ***(Right)*** *Transverse ultrasound of the same patient shows how the effusion* ➔ *is largely hypoechoic with a mild degree of synovial thickening* ➔. *A small amount of pus was aspirated. Culture was negative, probably because antibiotics had been administered empirically.*





(Left) *Longitudinal ultrasound of the posterior glenohumeral joint in a patient with severe shoulder pain, fever, and raised inflammatory markers shows moderate joint distension* ➔ *with severe synovial proliferation.* ***(Right)*** *Longitudinal ultrasound of the same patient shows subacromial-subdeltoid bursal distension* ➔ *with synovial proliferation. This bursa communicated with the glenohumeral joint via a supraspinatus tendon tear (not shown).*

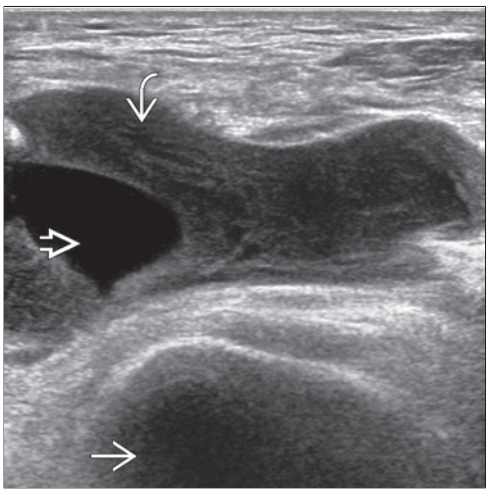


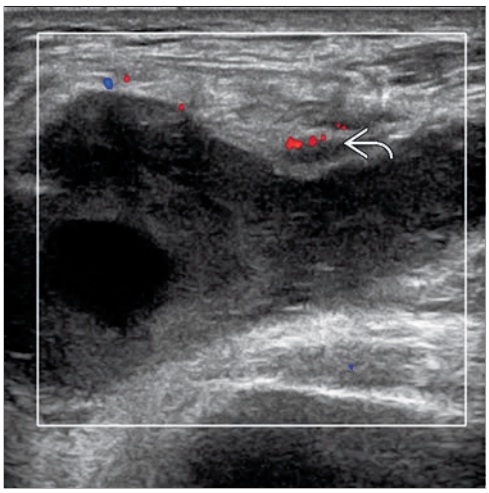


(Left) *Longitudinal color Doppler ultrasound of the same patient shows severe marginal hyperemia of the thickened synovium* ➔ *and peribursal tissues.* ***(Right)*** *Longitudinal ultrasound shows the same patient during Tru-Cut synovial biopsy* ⇨ *for histological and microbiological analysis. The synovial biopsy grew Staphylococcus epidermis while histology revealed acute on chronic inflammation.*

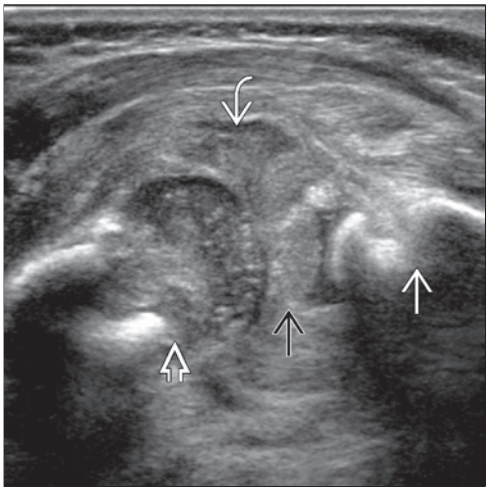
JOINT INFECTION

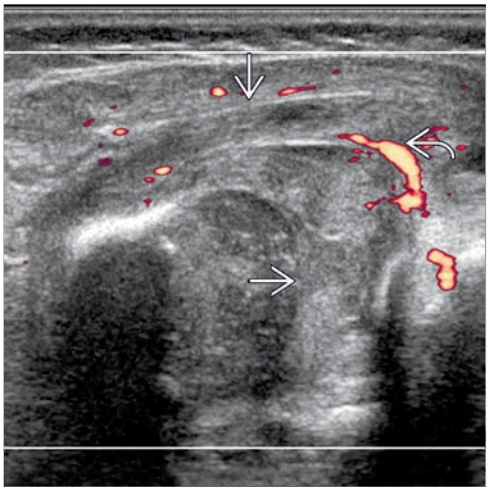
(Left) *Transverse ultrasound of a patient with chronic septic arthritis of the knee shows moderate to severe synovial proliferation with only a relatively small effusion. The distal femur is normal. **(Right)** Transverse color Doppler ultrasound of the same patient shows only mild peripheral hyperemia indicative of low-grade active inflammation. Aspirated joint fluid grew group G Streptococcus.*





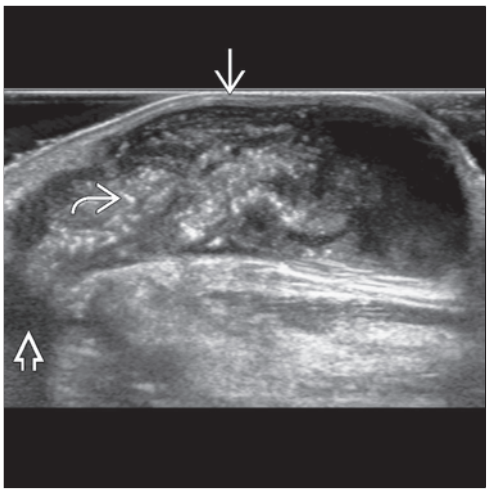
(Left) *Transverse ultrasound of a child with fever and shoulder pain shows severe diffuse synovial thickening of the glenohumeral joint. Only minimal fluid is present. Note the humeral head and scapula. **(Right)** Transverse power Doppler ultrasound of the same patient shows moderate hyperemia of the thickened synovium and adjacent soft tissues indicative of moderate-severity active inflammation. Joint aspirate grew group B Streptococcus agalactiae.*

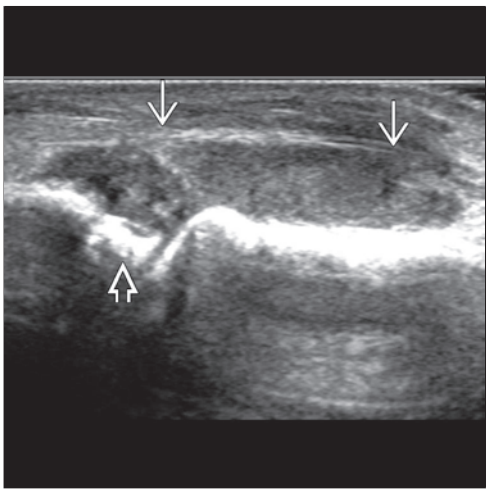


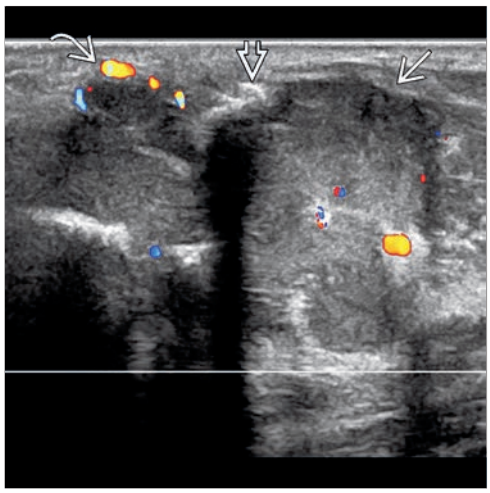


(Left) *Clinical photo of a patient with a slow-growing hand mass shows a focal swelling with skin discoloration on the dorsoradial aspect of the hand. **(Right)** Longitudinal ultrasound of the same patient shows a large heterogeneous mass with internal calcification and moving echoes on real-time imaging. This was due to a tuberculous cold abscess extending from the metacarpophalangeal joint into the subcutaneous soft tissues.*



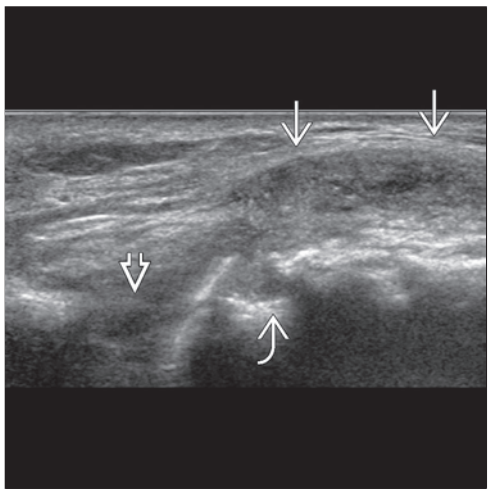




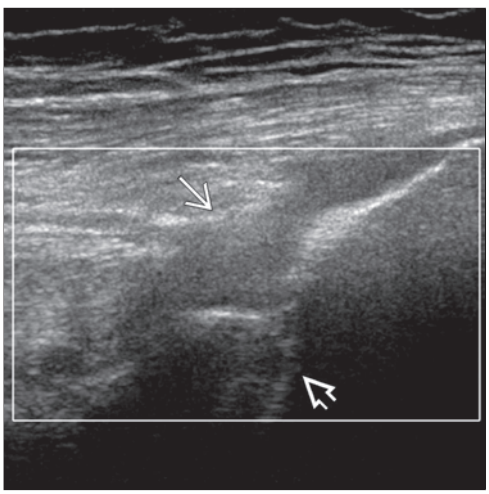


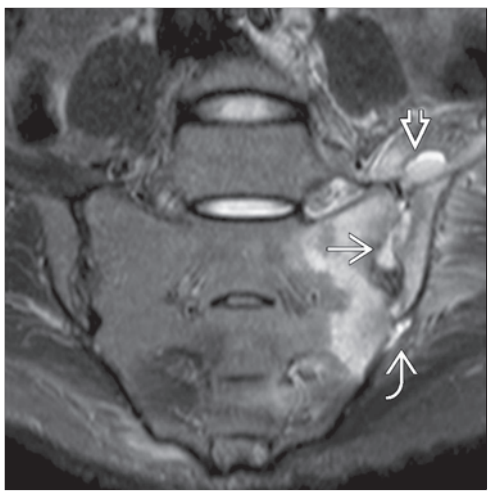
(Left) *Longitudinal ultrasound of a patient with progressive painless swelling of the thumb shows focal cortical irregularity at the proximal phalangeal base with echogenic intra- and extracapsular fluid as a result of capsular rupture.* ***(Right)*** *Transverse color Doppler ultrasound of the same patient shows a multilobulated collection with moving echoes, small calcific foci, posterior enhancement, and mild peripheral hyperemia. This was due to a tuberculous arthritis.*





(Left) *Clinical photo shows focal swelling with overlying skin erythema at the sternoclavicular joint region.* ***(Right)*** *Longitudinal ultrasound of the same patient shows widening of the sternoclavicular joint, bone erosion, and cortical irregularity of the medial clavicle with a moderate-sized paraarticular inflammatory mass. No effusion is evident. Ultrasound-guided biopsy of the inflammatory mass yielded Staphylococcus aureus.*





(Left) *Transverse color Doppler ultrasound of an intravenous drug user with Staphylococcus septicemia shows a small amount of inflammatory hypoechoic soft tissue posterior to the sacroiliac joint. No hyperemia is evident.* ***(Right)*** *Oblique coronal T2WI FS MR of the same patient shows sacroiliac joint widening with cortical erosion and periarticular marrow edema. Small fluid collections are present at the superior and inferior aspects of the joint. This was due to an infective sacroiliitis.*

POSTOPERATIVE INFECTION

Key Facts

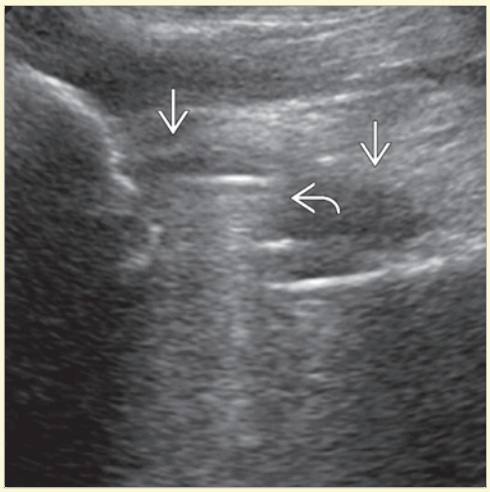
Terminology
- Infection at surgical site within 1 month of surgery or within 1 year of prosthetic implantation

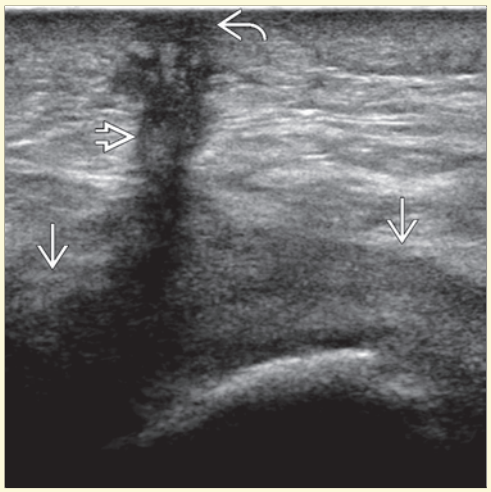
Imaging
- Mild soft tissue edema, fluid, & hyperemia are very common signs in early postoperative period
- Intensity & pattern of edema, fluid, & hyperemia helps differentiate infectious from noninfectious inflammation
  - Inflammation from surgical disruption of tissues & subsequent repair follows expected pattern & is usually mild in degree
  - Inflammation from postoperative infection is more severe & does not follow expected pattern
- Edematous tissue = hyperechoic if mildly edematous, hypoechoic if more intensely edematous
- Fluid may collect as discrete collection or as accumulation at fascial or tissue interface
  - Variable echogenicity
  - Cannot reliably differentiate between infected collection & noninfected collection
- Ultrasound is not prone to metallic artifact & is more suited to assessment of postoperative patient
- Ultrasound is not sensitive at detecting osteomyelitis

Top Differential Diagnoses
- Postoperative inflammation
- Hematoma
- Deep venous thrombosis

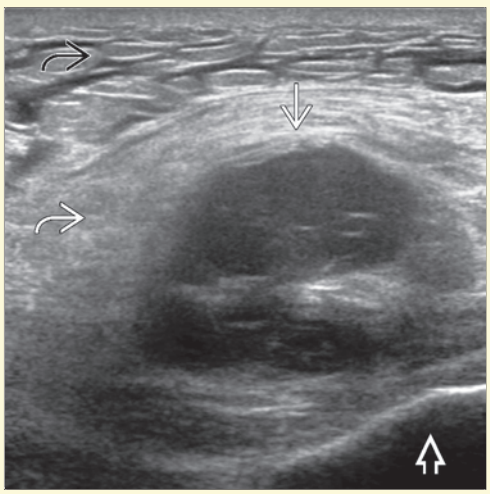
Diagnostic Checklist
- Ultrasound helps to define site of soft tissue infection, isolate fluid, & provide aspirate for culture
- ± ultrasound-guided soft tissue biopsy if no fluid collection is present
- Nuclear medicine studies help identify bone infection around prostheses

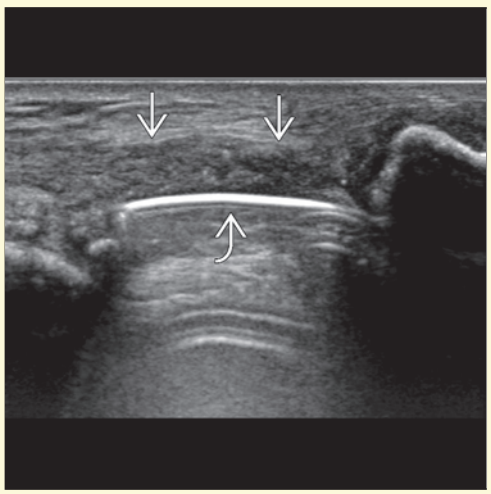
(Left) *Longitudinal ultrasound shows mild distension of the hip joint with a small amount of internal gas. This is a normal appearance 1 week after hip implant surgery.* ***(Right)*** *Longitudinal ultrasound of a patient with hip surgery 2 months previously shows a moderately thick band of granulation tissue extending from the distended hip joint to the cutaneous wound. Color Doppler ultrasound (not shown) revealed no significant hyperemia. This is a normal postoperative appearance.*





(Left) *Transverse ultrasound shows an infected hypoechoic collection in the lateral aspect of the proximal femur in a patient with revision of hip implant 2 weeks previously. There is moderate surrounding deep soft tissue edema and subcutaneous soft tissue edema.* ***(Right)*** *Transverse ultrasound of a patient with an infected elbow implant shows a moderate degree of inflammatory soft tissue and edema surrounding the implant.*





POSTOPERATIVE INFECTION

TERMINOLOGY

Definitions
- Infection at surgical site within 1 month of surgery or within 1 year of surgical implant

IMAGING

General Features
- Best diagnostic clue
  - Inflammation ± collection persisting > 1 week after surgery
- Location
  - Soft tissue, bone, or joint
  - Hip, knee, spine, or any operative site
- Morphology
  - From localized wound infection to acute osteomyelitis

Radiographic Findings
- Best initial investigation
  - Aids interpretation of subsequent ultrasound and other investigations
  - Progressive osteolysis is key to recognizing infection
  - Radiographs are normal in 50% of periprosthetic implant infections

CT Findings
- CECT
  - Multidetector CT is less prone to metallic artifact than MR
    - CT (or MR) provide most useful assessment of infection after implant has been removed
  - Delineates bony abnormality and soft tissue infection
    - ± CT-guided aspiration or drainage

MR Findings
- T1WI
  - MR imaging is often severely limited by metallic susceptibility artifact
  - Hypointense soft tissue swelling
- T2WI FS
  - Hyperintense soft tissue swelling ± hyperintense fluid or fluid collection
- T1WI C+
  - Infective, noninfective inflammatory, and reparative tissue all enhance
    - Generally, the greater the enhancement, the more likely the infection
  - Useful at delineating fluid collections
    - Degree of wall enhancement is greater with abscesses than with sterile collections

Ultrasonographic Findings
- Mild soft tissue edema, fluid and hyperemia are very common findings in early postoperative period
- Intensity and pattern of edema, fluid, and hyperemia helps differentiate infectious from noninfectious inflammation
  - Inflammation from surgical disruption of tissues and subsequent repair follows expected pattern and is usually mild in degree
  - Inflammation from postoperative infection is more severe and does not follow expected pattern
  - Assess soft tissue edema, presence of fluid and degree of hyperemia
- The greater the amount of soft tissue edema and inflammation, the greater the likelihood of postoperative infection
- Edematous tissue is hyperechoic if mildly edematous, hypoechoic if more intensely edematous
- Fluid may collect as discrete collection or as accumulation at fascial or tissue interfaces
  - Usually accumulates at most dependent areas
  - Anechoic or hypoechoic or hyperechoic
  - ± echogenic debris
  - Usually unable to distinguish between infected collection, noninfected seroma, or liquefied hematoma
    - Need to aspirate for bacteriological analysis
- Synovial/capsular thickening is common after surgery
  - Joint capsule disruption during surgery or arthroplasty
    - Limits development of postoperative effusion
      - In this context, there may be a joint infection with little, if any, joint effusion
    - Joint fluid drains into the periarticular tissues
  - Synovial thickening does not imply infection
    - Sometime need synovial biopsy
      - The greater the neutrophil count per high-power field in synovium, the greater the likelihood of implant infection
- ± gas around operative site
  - May be present normally a in few days after surgery or longer with open wound or drain inserted
- Ultrasound is not prone to metallic artifact
  - Good visualization of juxtacortical tissues
- Ultrasound can access most operative areas
- Helps localize site of infection (superficial or deep), identify drainable collection, and guide fluid aspiration or tissue biopsy for diagnosis
- Limitations of ultrasound
  - Cannot differentiate mild postoperative infection from noninfective postoperative inflammation
  - Transducer access is occasionally limited by external fixators, bandaging, or cutaneous wound
    - Some areas (such as spine) have very limited transducer access
  - Not sensitive at detecting osteomyelitis

Nuclear Medicine Findings
- Bone scan
  - Used for diagnosis of periprosthetic infection and best if combined with labeled leukocyte scintigraphy or gallium scintigraphy
  - No periprosthetic uptake = no infection
  - Periprosthetic uptake indicates loosening or infection
    - Uptake at same site on labeled leukocyte scintigraphy or gallium scintigraphy makes infection most likely
    - No uptake at same site on labeled leukocyte scintigraphy or gallium scintigraphy makes loosening most unlikely
  - High sensitivity with moderate specificity
    - Repair can simulate infection
- PET/CT

POSTOPERATIVE INFECTION

- Combines high sensitivity of PET imaging with high resolution of CT imaging
  - ↓ specificity, particularly in postoperative cases
  - Glucolysis also feature of noninfectious inflammation and repair
- Activity around shaft and tip of hip prosthesis increases likelihood of infection compared to activity around head and neck of prosthesis

Imaging Recommendations

- Best imaging tool
  - Ultrasound
- Protocol advice
  - Remove bandaging; cover suture line with thin polyurethane adhesive dressing
  - Copious gel to maximize transducer contact at surgical incision
  - Examine dependent areas carefully since collections will accumulate here preferentially
    - e.g., following hip arthroplasty, roll patient to lateral decubitus position to examine gluteal and posterior thigh regions
  - Perform ultrasound-guided aspiration of joint or fluid collection ± ultrasound-guided biopsy of synovium or inflammatory soft tissue
    - If performing aspiration, ensure aseptic technique, as damaged tissues are particularly susceptible to bacterial inoculation

DIFFERENTIAL DIAGNOSIS

Postoperative Inflammation

- Difficult to distinguish from postoperative infection
- Pattern and intensity of edema, fluid accumulation, and degree of hyperemia are relevant to making this distinction

Hematoma

- Hypoechoic avascular mass with fixed fine internal echoes

Deep Venous Thrombosis

- May coexist with postoperative infection
- Noncompressible vein

PATHOLOGY

General Features

- Etiology
  - Incidence of infection following knee or hip arthroplasty = 0.5-2%
    - Early infection (< 3 months after surgery) is mostly due to surgical contamination
    - Late infection (within 1 year of surgery) is mostly due to hematogenous seeding of operative site
    - Prostheses: Disrupt integrity of tissues, affect blood supply, and provide surface for bacterial adherence
  - *Staphylococcus aureus*
    - Responsible organism in half of cases
  - Gram-negative bacilli (*Bacteroides*, *Escherichia coli*, *Pseudomonas*, *Proteus*, *Klebsiella*, *Enterococcus*)

Gross Pathologic & Surgical Features

- Cellulitis, pyomyositis, abscess

Microscopic Features

- Acute or acute on chronic inflammatory infiltrate, capillary dilatation ± abscess formation

CLINICAL ISSUES

Presentation

- Most common signs/symptoms
  - Pain and swelling
- Other signs/symptoms
  - Wound oozing, inflammation, fever
- Clinical profile
  - Leukocytosis, raised inflammatory markers

Demographics

- Age
  - Less common in young patients
- Epidemiology
  - Risks related to surgery
    - Long operation time (> 3 hours), high blood loss (> 1,000 mL), instrumentation, multiple surgical sites (e.g., fixation + bone grafting), staged operation or repeat operation
  - Risks related to patient
    - Frailty, coexistent morbidity, coexistent remote site infection, obesity, smoking

Natural History & Prognosis

- Superficial infection can usually be treated successfully with antibiotic therapy
- Established deep infection is often difficult to eradicate without removing implant

Treatment

- Antibiotic therapy
- Aspiration or drainage (ultrasound-guided) of collection or collections
- ± debridement
- ± implant removal and revision

DIAGNOSTIC CHECKLIST

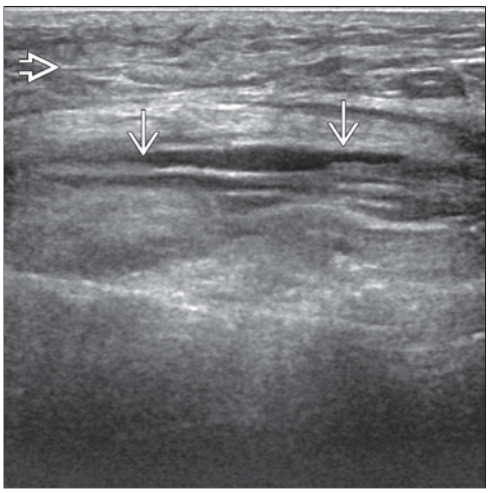
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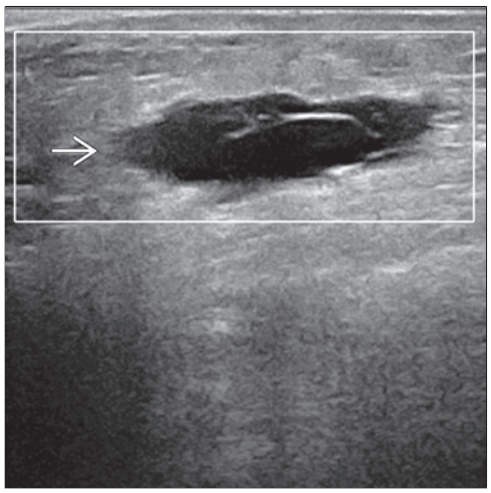
- Accurate and timely recognition is key to successful eradication of postoperative infection
- Most postoperative infections are clinically evident
  - Ultrasound helps to define site of soft tissue infection, isolate fluid, and provide aspirate for culture
  - Nuclear medicine studies help identify bone infection around prostheses
- Integrity of recently operated bone is impaired
  - If juxtacortical infection present, high probability that bone is also infected

SELECTED REFERENCES

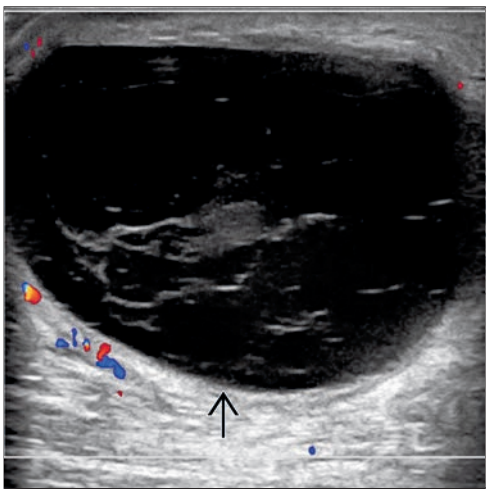
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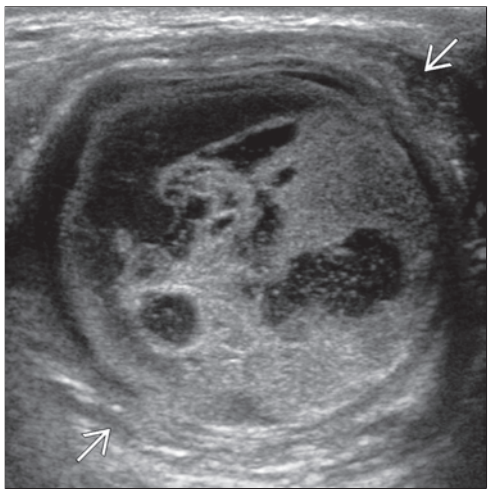
POSTOPERATIVE INFECTION



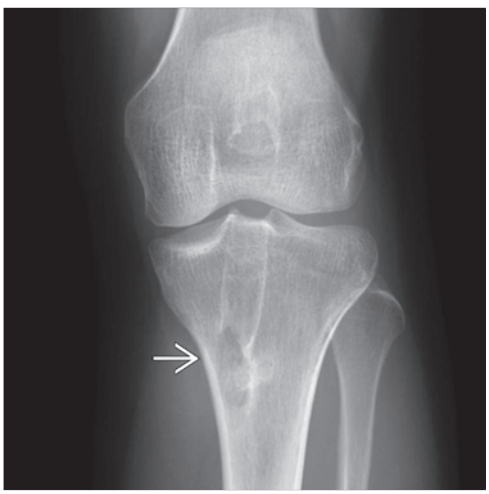


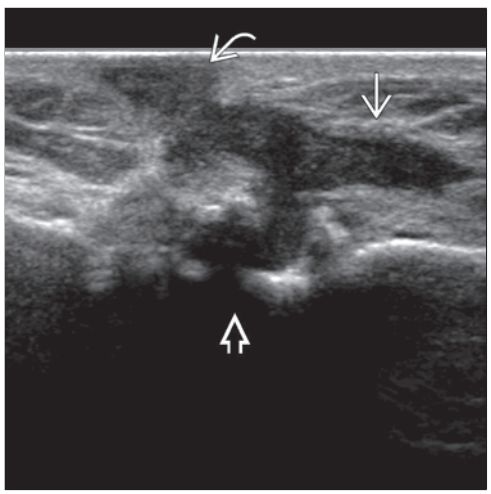
(Left) *Longitudinal ultrasound of a patient with recent hip surgery shows a small amount of fluid* ➔ *in the immediate subfascial soft tissues with mild subcutaneous soft tissue edema* ➔. ***(Right)*** *Transverse color Doppler ultrasound of the same patient at a more posterior location shows a small subcutaneous fluid collection* ➔. *No significant hyperemia is present. Small fluid collections near the surgical site are a common finding in the early postoperative period.*





(Left) *Transverse color Doppler ultrasound of a patient after groin surgery shows a large subcutaneous collection* ➔ *with multiple thin septations and mild marginal hyperemia. This is a seroma. Ultrasound cannot reliably differentiate infected from noninfected collection. Aspiration is necessary.* ***(Right)*** *Transverse ultrasound of a patient after groin surgery shows an echogenic collection* ➔ *with a thickened wall and multiple fine internal echoes due to an infected organizing hematoma.*

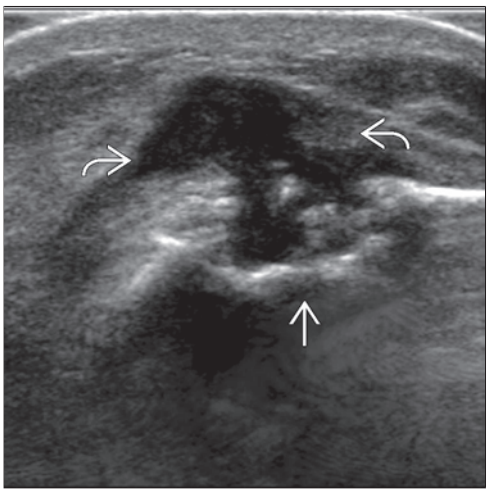


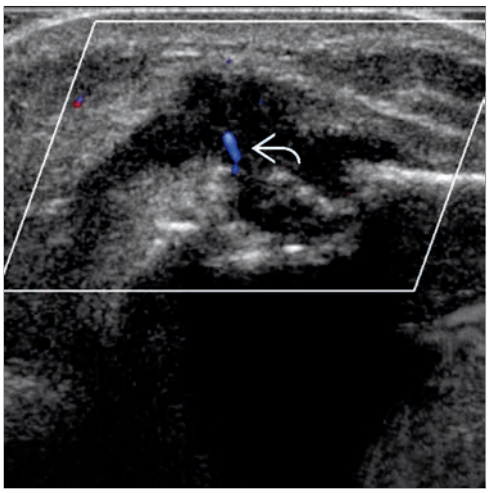


(Left) *Frontal radiograph of a patient with previous anterior cruciate ligament grafting shows an area of osteolysis* ➔ *with a partially sclerotic border at the proximal end of the tibial tunnel.* ***(Right)*** *Longitudinal ultrasound of the same patient shows hypoechoic inflammatory tissue* ➔ *adjacent to the tibial tunnel cortical defect* ➔ *extending to the skin* ➔. *This radiographic and ultrasound picture is consistent with postoperative infection of the tibial tunnel.*

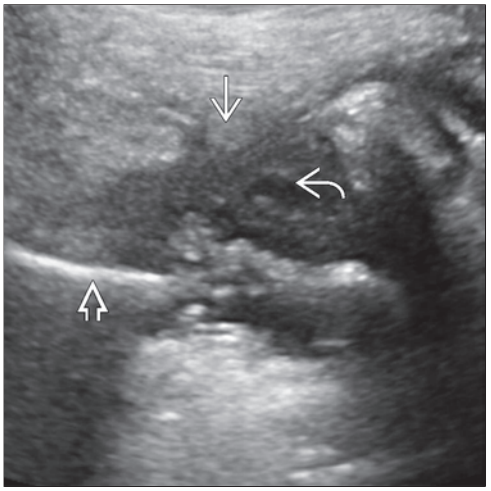
POSTOPERATIVE INFECTION

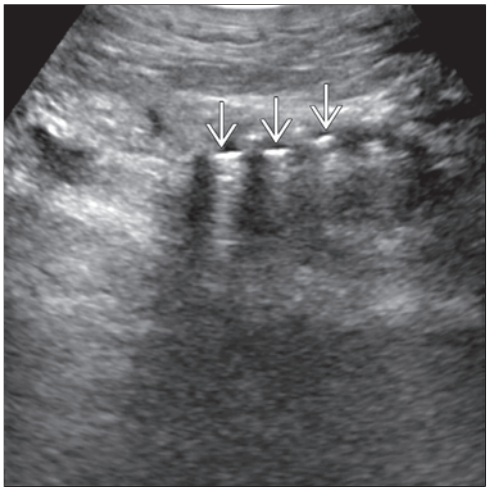
(Left) *Transverse ultrasound of the same patient shows moderate cortical irregularity* ➔ *around the tibia tunnel opening with juxtacortical hypoechoic inflammatory tissue* ➔. ***(Right)*** *Transverse color Doppler ultrasound of the same patient shows a mild degree of hyperemia* ➔ *within the hypoechoic inflammatory soft tissue. This hyperemia is helpful at distinguishing hypoechoic inflammatory tissue from fluid.*



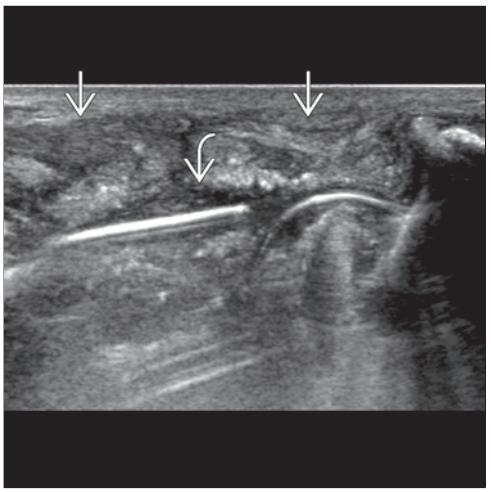


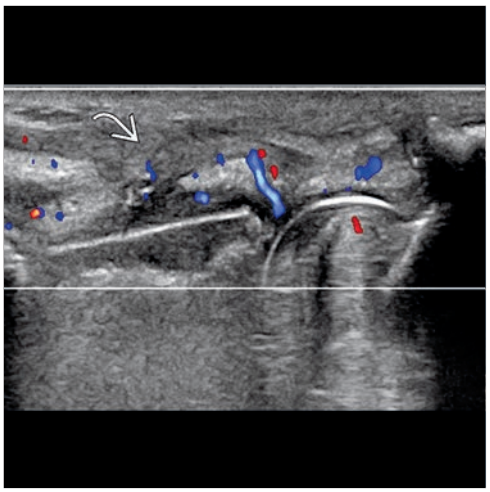
(Left) *Longitudinal ultrasound shows a periprosthetic infection of the hip with a moderate degree of hypoechoic inflammatory soft tissue* ➔ *adjacent to the prosthesis* ➔. *There is a small anechoic fluid component* ➔ *within the inflammatory soft tissue.* ***(Right)*** *Longitudinal ultrasound of the same patient in a slightly more lateral location shows multiple echogenic foci* ➔ *due to surgically implanted antibiotic beads within the soft tissues.*





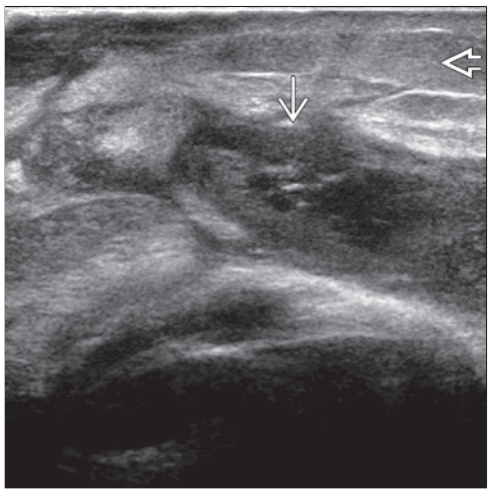
(Left) *Longitudinal ultrasound of a patient with an infected elbow replacement shows severe periprosthetic soft tissue edema* ➔. *There is a small amount of fluid or very edematous inflammatory tissue* ➔ *immediately alongside the prosthesis.* ***(Right)*** *Longitudinal color Doppler ultrasound of the same patient shows moderate hyperemia* ➔ *of the inflamed periprosthetic soft tissues. The periprosthetic hypoechogenicity is due to edematous inflammatory tissue rather than fluid.*



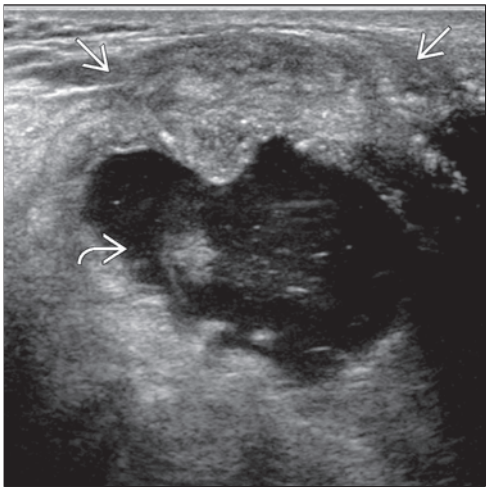


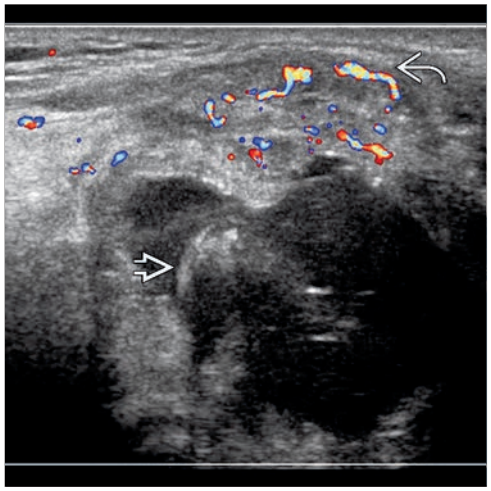
POSTOPERATIVE INFECTION



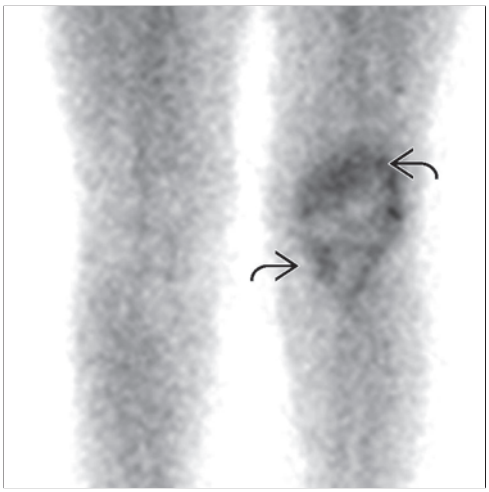


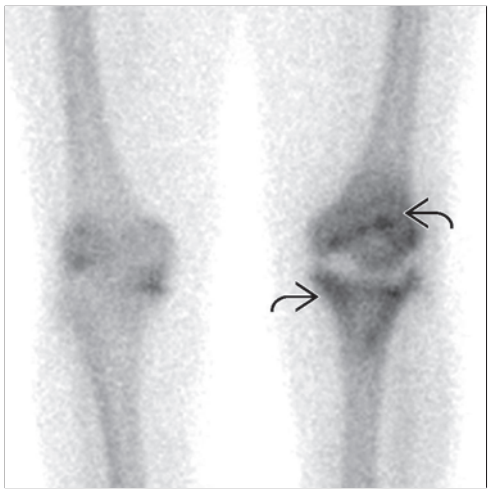
(Left) *Clinical photo of a patient with previous total knee replacement shows swelling and erythema of the skin around the surgical scar.* ***(Right)*** *Longitudinal ultrasound of the same patient shows moderate synovial proliferation of the suprapatellar pouch with moderate surrounding soft tissue edema due to an infected implant.*





(Left) *Transverse ultrasound of a patient with infected total knee replacement for osteoarthritis shows severe synovial proliferation with a moderate amount of mildly echogenic joint fluid.* ***(Right)*** *Transverse color Doppler ultrasound of the same patient shows moderate to severe synovial hyperemia indicative of moderately active infective synovitis. Note the echoes within the joint effusion.*





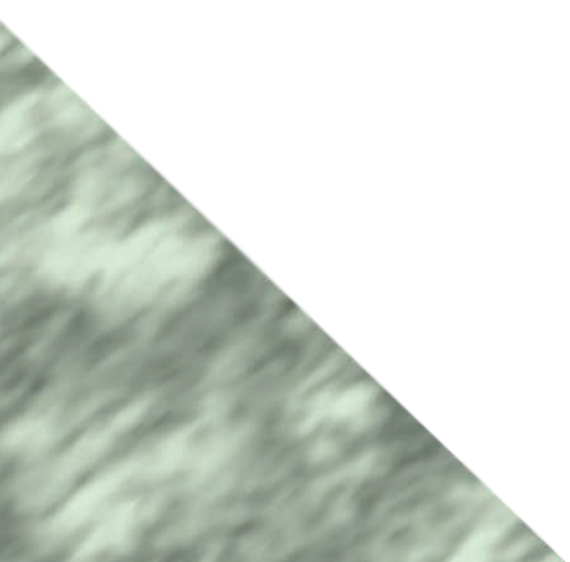
(Left) *Three-phase bone scan of the same patient shows increased periprosthetic activity in the early perfusion phase indicative of hyperemia. There was also increased activity in the blood pool phase (not shown).* ***(Right)*** *Three-phase bone scan of the same patient shows increased periprosthetic activity in the delayed phase. This can be due to prosthetic loosening or infection. Additional gallium scan revealed increased tracer accumulation at the same sites indicative of infection.*



SECTION 7

Articular and Paraarticular Masses

Hemarthrosis and Lipohemarthrosis **II**-7-2
Baker Cyst **II**-7-6
Bursitis **II**-7-12
Ganglion Cyst **II**-7-24
Parameniscal Cyst **II**-7-34
Synovial Tumor **II**-7-38



HEMARTHROSIS AND LIPOHEMARTHROSIS

Key Facts

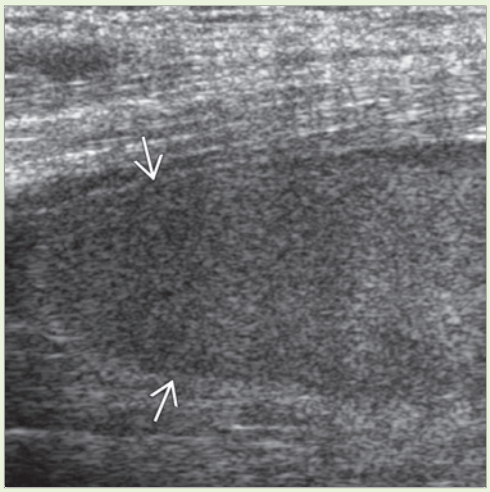
Terminology
- Hemarthrosis: Blood in joint cavity
- Lipohemarthrosis: Blood and fat in joint cavity

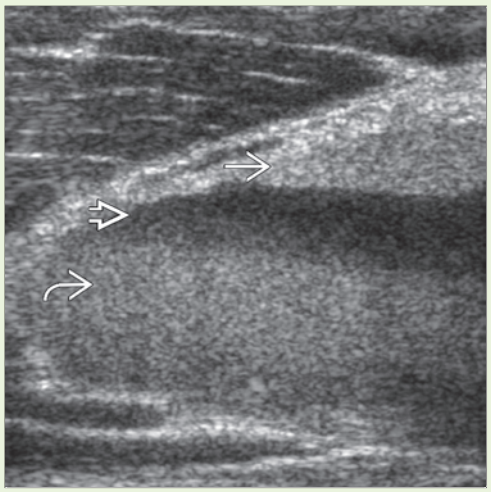
Imaging
- Layered joint effusion
- **Hemarthrosis is initially seen as finely speckled echogenic joint fluid**
  - After ~ 5 minutes, may become 2-layered joint effusion
  - Superficial hypoechoic layer represents supernatant serum
  - Deep hyperechoic layer represents dependent RBCs
- **Lipohemarthrosis is initially seen as finely speckled echogenic joint fluid**
  - After ~ 10 minutes, may become 3-layered joint effusion
  - Superficial hyperechoic layer represents floating fat
  - Central hypoechoic layer represents supernatant serum
  - Deep hyperechoic layer represents dependent red blood cells
  - ± hypoechoic areas within floating fat due to trapped blood

Top Differential Diagnoses
- Septic arthritis
- Gout
- Inflammatory synovitis

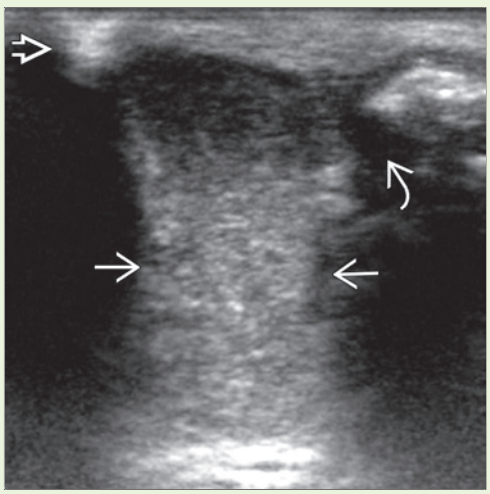
Diagnostic Checklist
- Lipohemarthrosis is an uncommon finding but, when present, is an absolute indicator of continuity with the marrow cavity, nearly always from fracture; postsurgical continuity is a much less common cause

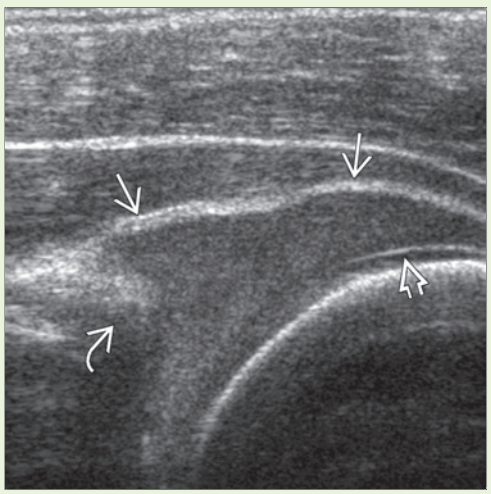
(Left) *Longitudinal US of the suprapatellar pouch following knee trauma shows that the joint capsule is distended with echogenic fluid. No layering or sedimentation is present.* ***(Right)*** *Longitudinal US repeated 15 minutes later at the same location (same patient) shows the 3-layered appearance of a lipohemarthrosis. The fat layer, serum layer, and cellular (red blood cell) layer are now apparent.*





(Left) *Oblique US of the lateral aspect of the elbow joint shows acute hemarthrosis in a hemophiliac patient. Note the irregular radial head. The edge of the capitellum is also shown.* ***(Right)*** *Transverse US of the posterior aspect of the shoulder shows acute hemarthrosis with a distended joint capsule. No layering is present. The glenoid labrum is shown, and so is the articular cartilage of the humeral head. Shoulder hemarthrosis may accompany massive rotator cuff tear.*





HEMARTHROSIS AND LIPOHEMARTHROSIS

TERMINOLOGY

Synonyms
- Post-traumatic hemarthrosis or lipohemarthrosis
- Spontaneous hemarthrosis
- Hemophiliac arthropathy

Definitions
- Hemarthrosis: Blood in joint cavity
- Lipohemarthrosis: Blood and fat in joint cavity
  - Very specific for intraarticular fracture
- Spontaneous hemarthrosis: Hemarthrosis developing in absence of predisposing trauma, synovial tumor, or hemophilia
- Hemophiliac arthropathy: Arthropathy secondary to repeated hemarthrosis due to inherited clotting disorder

IMAGING

General Features
- Best diagnostic clue
  - Layered joint effusion
- Location
  - Knee > ankle > elbow > shoulder > hip

Radiographic Findings
- Hyperdense joint effusion
  - Density of hemorrhage > synovial fluid
- Horizontal beam radiography: Fat-fluid level due to differences in attenuation fat and blood components
  - Fat is less dense and thus floats on surface of blood
  - Lipohemarthrosis is present in 35% of intraarticular fractures around knee
    - High specificity but low sensitivity for intraarticular fractures

CT Findings
- NECT
  - Hemarthrosis: 2 distinct layers
    - Superficial isodense layer (~ 30 Hounsfield units [HU]) = serum
    - Deep hyperdense layer (~ 70 HU) = red blood cells (RBCs)
  - Lipohemarthrosis: 3 distinct layers
    - Superficial hypodense layer (~ -70 HU) = fat
    - Central intermediate layer (~ 20 HU) = serum
    - Deep hyperdense layer (~ 90 HU) = RBCs

MR Findings
- T2WI
  - Hemarthrosis: 2 distinct signal bands
    - Superficial hypointense band = serum
    - Deep isodense band = dependent RBCs
  - Lipohemarthrosis: 3 distinct signal bands
    - Superficial hyperintense band = floating fat
    - Central hyperintense band = serum
    - Deep isointense band = dependent RBCs
    - ± thin hypointense band due to chemical shift artifact at serum-fat interface

Ultrasonographic Findings
- Acute stage
  - Large effusion
    - Finely speckled echogenic joint fluid
    - Minimal or no synovial thickening or hyperemia
  - ± graded ↑ echogenicity from more hypoechoic (superficial) to more hyperechoic (deep)
    - Due to early sedimentation of cellular elements
  - ± layering of different fluid components
    - Specific for hemarthrosis or lipohemarthrosis
    - Seen after part under examination is static for few minutes
  - **Hemarthrosis is initially seen as uniformly finely speckled echogenic joint fluid**
    - After ~ 5 minutes, may become 2-layered joint effusion
      - Superficial hypoechoic layer representing supernatant serum
      - Deep hyperechoic layer representing dependent RBCs
  - **Lipohemarthrosis is initially seen as uniformly finely speckled echogenic joint fluid**
    - After ~ 10 minutes, may become 3-layered joint effusion
      - Superficial hyperechoic layer representing floating fat
      - Central hypoechoic layer representing supernatant serum
      - Deep hyperechoic layer representing dependent RBCs
    - ± hypoechoic areas within floating fat due to trapped blood
  - Demonstration of layers probably depends on 3 factors
    - Amount of blood or fat in joint
    - Time part under examination is static prior to imaging
    - Time after fracture
- Subacute stage
  - Blood clots: Discrete echogenic foci within joint
  - Joint fluid: More anechoic
  - ± fibrinous adhesions
- Repeated hemarthrosis
  - Early hemophiliac arthropathy: ↑ joint fluid, mild to moderate synovial proliferation with synovial hyperemia
  - Late hemophiliac arthropathy: Less joint fluid, severe synovial thickening with ↓ intensity of synovial hyperemia
    - Hemosiderin deposition is not apparent on US
  - Secondary osteoarthrosis
    - Joint space narrowing
    - Marginal osteophytosis
    - ± meniscal extrusion
    - Subchondral bony erosions and subchondral cysts are not usually visible on US
  - ± Baker cyst
  - ± pseudotumor (expanding hematoma)
    - Hypoechoic ± hyperechoic areas (recent bleeding) ± anechoic areas (liquefaction)

Imaging Recommendations
- Best imaging tool
  - Ultrasound
- Protocol advice
  - Minimize movement of part under examination
  - Repeat examination at 5-20 minutes to observe layering

HEMARTHROSIS AND LIPOHEMARTHROSIS

DIFFERENTIAL DIAGNOSIS

Septic Arthritis
- Gradual-onset joint swelling over 1-2 days
  - More insidious onset if nonpyogenic infection
- Very tender with marked limitation of movement
  - More severe inflammation than hemarthrosis/lipohemarthrosis
  - Aspirate if there is any doubt

Gout
- Severe inflammation with moderate synovial proliferation
- Echogenic crystal aggregates ± tophi
- Aspirate if there is any doubt

Inflammatory Synovitis
- Moderate to severe synovial proliferation and hyperemia
- ± polyarticular ± marginal erosions
- ± joint space narrowing
- Aspirate if there is any doubt

PATHOLOGY

General Features
- Etiology
  - Post-traumatic hemarthrosis/lipohemarthrosis
    - Bleeding from laceration of synovial vessels or leakage from marrow cavity
    - Lipohemarthrosis always signifies intraarticular fracture extension
    - Only way marrow fat can enter joint
  - Spontaneous hemarthrosis
    - Due to spontaneous bleeding from synovium
- Genetics
  - Hemophilia A or B: X-linked recessive

Staging, Grading, & Classification
- Arnold-Hilgartner scale for hemophiliac arthropathy of knee
  - Stage 0: Normal joint
  - Stage I: Soft tissue swelling
  - Stage II: Osteoporosis and overgrowth of epiphysis
  - Stage III: Early subchondral bone cysts, squaring of patella, widening of intercondylar notch
  - Stage IV: As per stage III but joint space is narrowed
  - Stage V: Fibrous joint contracture, loss of joint space, severe enlargement of epiphysis, and substantial disorganization of joint

Gross Pathologic & Surgical Features
- Synovial proliferation and inflammation (if hemophiliac arthropathy)
- Arthropathy

Microscopic Features
- Acute on chronic inflammation
- Hemosiderin-laden macrophages; fibrosis

CLINICAL ISSUES

Presentation
- Most common signs/symptoms
  - Rapid-onset joint effusion
- Other signs/symptoms
  - Tense, warm joint
    - Arterial or venous bleeding

Demographics
- Age
  - Post-traumatic hemarthrosis/lipohemarthrosis: Most common at 20-30 years
  - Spontaneous hemarthrosis: Most common in middle-aged or elderly individuals
  - Hemophiliac arthropathy: Occurs throughout life, even in neonates
- Gender
  - Hemarthrosis and lipohemarthrosis: M > F
    - Related to increased trauma prevalence in males
  - Hemophilia: Almost exclusively in males
- Epidemiology
  - Relative frequency: Hemophilia A (85%), hemophilia B (14%), other clotting disorders (1%)
    - 1 in 5,000 males; 60% of cases are severe

Natural History & Prognosis
- Acute hemorrhage resolves over 1-2 weeks
- Hemophiliac arthropathy
  - Repeated hemarthrosis → progressive arthropathy

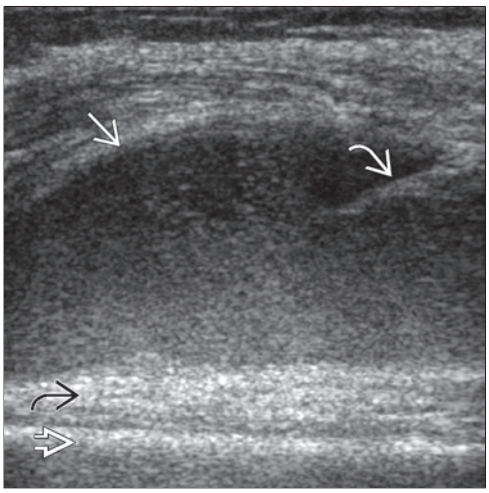
Treatment
- Rest and analgesia
  - ± aspiration if very painful (distension)
- Hemophiliac arthropathy with acute hemorrhage
  - Rest and ice
  - Correct coagulation factor deficiency
    - Infusion of factor VIII (hemophilia A) or factor IX (hemophilia B)
- Hemophiliac arthropathy with repeated hemarthroses
  - Chemical synovectomy with intraarticular administration of rifampicin or osmic acid (± US guidance)
  - Radiosynovectomy with intraarticular administration of yttrium, gold, or phosphorus (± US guidance)
    - Induces synovial fibrosis and leads to reduced bleeding
    - Extraarticular injection or leakage leads to radiation burn ± inflammatory reaction
    - Contraindicated if leaking Baker cyst
  - Intraarticular administration of hyaluronic acid (± US guidance)
  - Surgery: Joint replacement (if severe arthropathy)

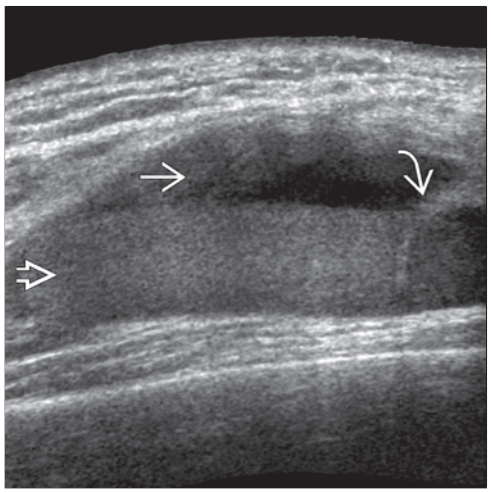
DIAGNOSTIC CHECKLIST

Image Interpretation Pearls
- Lipohemarthrosis has single-fluid level (fat-fluid) on radiography but double-fluid level (fat-serum-RBCs) on US, CT, and MR
  - Cross-sectional imaging allows one to differentiate serous and cellular components of blood

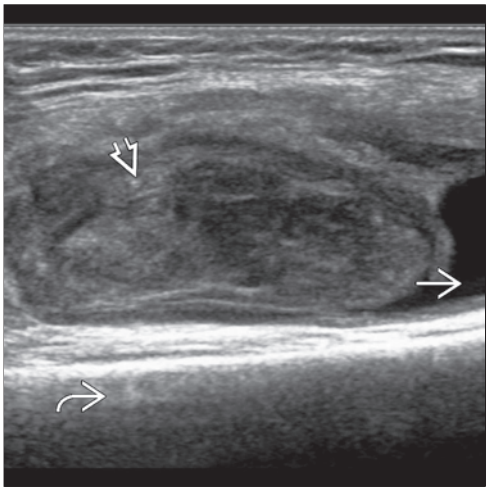
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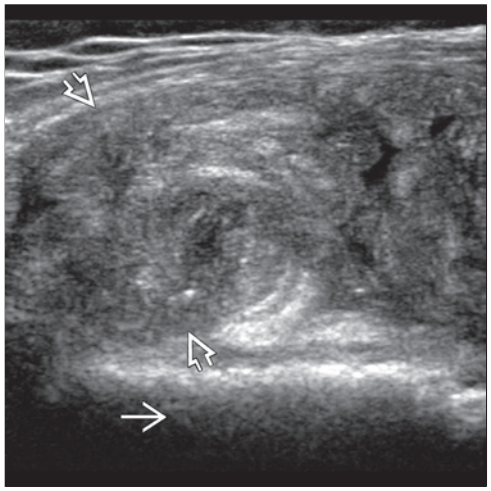
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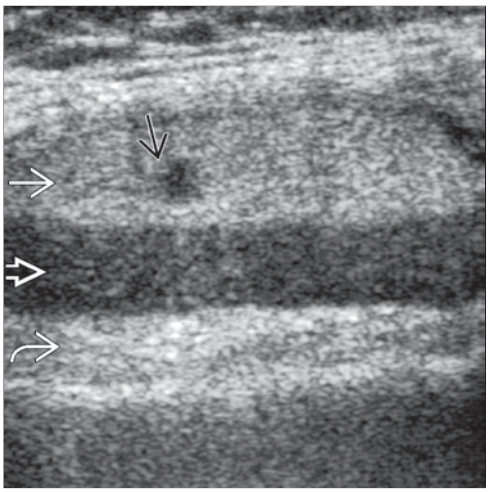


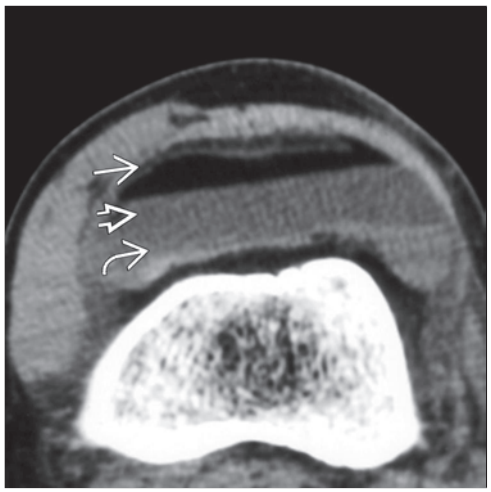
(Left) *Longitudinal US of the suprapatellar pouch in acute hemarthrosis demonstrates sedimentation evidenced by gradually increasing echogenicity from superficial to deep. Note the prefemoral fat, femoral cortex, and synovial fold.* ***(Right)*** *Longitudinal US repeated 10 minutes later (same patient) shows acute hemarthrosis with a 2-layer appearance: Serum layer and cellular (RBC) layer. Note the synovial plica (fold) traversing the suprapatellar pouch.*





(Left) *Longitudinal US shows an acute hematoma in the suprapatellar pouch of a hemophiliac patient. There is an anechoic joint effusion. The distal femur is shown.* ***(Right)*** *Longitudinal US shows a combination of acute hemarthrosis and synovial proliferation in the suprapatellar pouch of a hemophilic patient with an acute onset of knee swelling. In this context, it is not always easy to separate hemorrhage from synovium. The distal femur is shown.*





(Left) *Transverse US of the suprapatellar pouch shows a lipohemarthrosis with fat, serum, and cellular layers. The hypoechoic area in the fat layer is due to the entrapped blood.* ***(Right)*** *Axial NECT shows lipohemarthrosis in the suprapatellar pouch of the knee. The 3-layered appearance is produced by separate layering of the fat, serum, and cellular (RBC) components.*

BAKER CYST

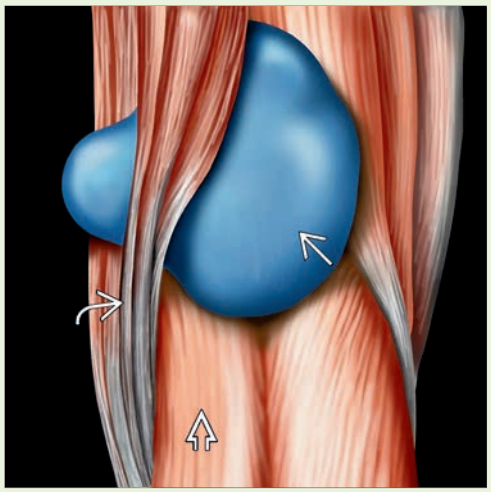
Key Facts

Imaging

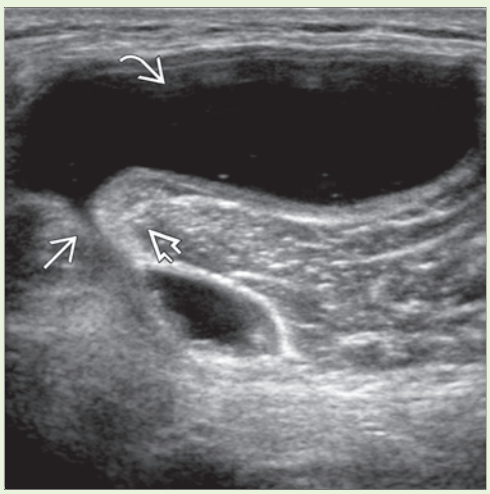
- Fluid-filled sac with neck arising from interspace between gastrocnemius muscle & semimembranosus tendon
- Characteristic "talk-bubble" configuration on transverse scans
- Cysts are typically well defined & thin walled
- Thick-walled cysts suggest inflammatory knee arthropathy or intracystic hemorrhage
- Thick-walled cysts often have hyperemic walls
- Cyst may be septated
- Contains anechoic synovial fluid, typically gelatinous in consistency
- Free fluid tracking adjacent to cyst indicates recent leakage
- Irregular & multiloculated cysts may result from repeated cyst leakage & collection
- Cysts usually extend distally superficial to medial belly gastrocnemius muscle
- Contralateral subclinical Baker cysts common
- Ultrasound accurately confirms presence, extent, & content of Baker cyst
- Examine with patient prone, knees extended
- Follow medial belly of gastrocnemius proximally & locate interspace between medial gastrocnemius head & semimembranosus tendon
- Routinely examine contralateral side
- Can aspirate percutaneously, if not too viscous, but high rate of recurrence
  - ± steroid injection, especially if inflammatory component is present (inflammatory-type exudate, thick walled, hyperemia)
  - Not possible to ascertain viscosity of cyst content from ultrasound appearance

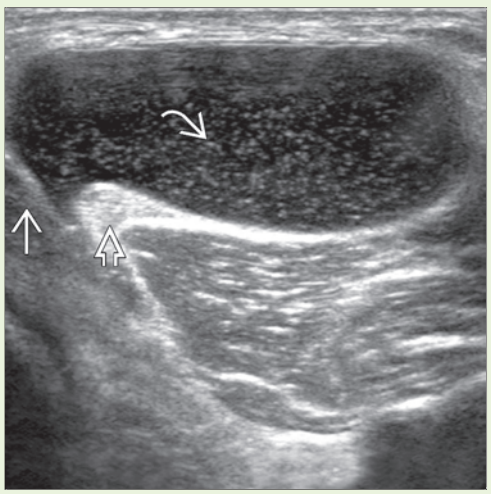
(Left) *Clinical photograph of the popliteal fossa shows focal swelling due to Baker cyst. Most patients with Baker cyst just have a palpable swelling rather than a visible focal fullness.* ***(Right)*** *Longitudinal graphic shows a Baker cyst located between the semimembranosus tendon & the medial belly of the gastrocnemius muscle.*





(Left) *Transverse ultrasound shows a typical Baker cyst with a "talk-bubble" configuration. The neck extends between the semimembranosus tendon & the medial belly of the gastrocnemius muscle.* ***(Right)*** *Transverse ultrasound shows a typical Baker cyst with the neck arising between the semimembranosus tendon & the medial belly of the gastrocnemius muscle. Note the finely speckled fluid within the cyst, representing colloid aggregates.*





BAKER CYST

TERMINOLOGY

Synonyms
- Popliteal cyst, popliteal synovial cyst
  - Baker cyst is preferred term since popliteal cyst can also refer to periarticular ganglion cyst or parameniscal cyst

Definitions
- Fluid distension of gastrocnemius-semimembranosus bursa

IMAGING

General Features
- Best diagnostic clue
  - Fluid-filled sac with neck arising from interspace between gastrocnemius muscle & semimembranosus tendon
- Location
  - Posterior to medial femoral condyle
- Size
  - Range: 1-30 cm across long axis or greater
- Morphology
  - Small unilocular sac to large multiloculated sac extending to mid 1/3 of calf

Radiographic Findings
- Radiography
  - Soft tissue swelling of posteromedial knee
    - ± calcified debris
    - ± displacement of calcified popliteal artery

MR Findings
- T1WI
  - Hypointense well-defined mass in expected location
  - Subacute hemorrhage in cyst seen as areas of hyperintensity
- T2WI
  - Hyperintense mass: Gastrocnemius-semimembranosus bursa
    - ± debris
    - ± hemorrhage (fluid level/hypointense foci-hemosiderin)
    - ± calcified bodies (hypointense)
    - ± thick synovial wall
  - ± hyperintense surrounding fluid
    - Indicates leakage or rupture
- T2* GRE
  - Sensitive to hypointense foci of hemosiderin

Ultrasonographic Findings
- Fluid-filled popliteal fossa mass
  - Anechoic with posterior enhancement
  - Must see neck arising from medial gastrocnemius-semimembranosus tendon interspace to make diagnosis of Baker cyst
    - Characteristic "talk-bubble" configuration on transverse scan
  - Extension through posterior knee capsule not seen
- Cysts typically well defined & thin walled
  - No wall hyperemia
- Thick-walled cysts suggest inflammatory knee arthropathy or intracystic hemorrhage
  - Thick-walled cysts often have hyperemic walls
- Cyst may be septated
  - Usually bilocular or trilocular
- Typically contains anechoic synovial fluid, gelatinous in consistency
  - Swirling fluid artifact is not a feature
  - ± fine echogenic speckles due to colloid aggregations
  - ± small echogenic "comet tail" artifacts (secondary to colloid aggregates)
  - ± fibrinous-type exudate (particularly with inflammatory arthropathy)
  - ± calcific particulate matter
  - ± blood clots
- Iso- or hyperechoic fluid suggests recent intracystic bleeding or inflammatory exudate
- Free fluid tracking adjacent to cyst indicates recent leakage
  - Irregular & multiloculated cysts most likely result from repeated cyst leakage & collection
  - Sharp angular margins to cyst contour also suggest leakage
    - Fluid leaked from Baker cyst will not have discernible wall
- Cysts usually extend distally superficial to medial belly of gastrocnemius muscle
  - ± extension distally deep to medial belly of gastrocnemius
  - ± extension proximally deep to and around hamstring muscles, especially semimembranous muscle
  - ± intramuscular extension (rare)
    - Into medial belly gastrocnemius, vastus medialis
    - Through muscular fascia weakened by trauma or perforating vessels
- Contralateral subclinical Baker cysts are common
  - Routinely examine both popliteal fossae

Imaging Recommendations
- Best imaging tool
  - Ultrasound
    - Confirms presence, extent, & content
- Protocol advice
  - Examine with patient prone, knees extended
  - Follow medial belly of gastrocnemius proximally & locate interspace between medial gastrocnemius head & semimembranosus tendon
    - Baker cyst arises from interspace between these 2 structures
    - Check cyst margins closely looking for fluid leakage, especially more distal margin
  - Routinely examine contralateral side

DIFFERENTIAL DIAGNOSIS

Parameniscal Cyst
- Usually associated with meniscal tear, typically horizontal tear
- Cyst extends to contact or very close to margin of meniscus
- Does not have typical configuration of Baker cyst

Popliteal Artery Aneurysm
- Saccular or fusiform dilation of popliteal artery
- Color Doppler imaging confirms vascular flow in aneurysm

BAKER CYST

Cystic Paraarticular Tumor
- Cystic synovial sarcoma or myxoma
- Does not have typical configuration of Baker cyst

PATHOLOGY

General Features
- Etiology
  - Joint fluid decompressing into cyst
  - Fluid may communicate freely or be restricted with ball valve-like mechanism
- Associated abnormalities
  - Effusion associated with intraarticular pathology in ~ 85-98% of cases in adults
    - Meniscal tears, arthritis (degenerative, inflammatory), chondral defects, cruciate ligament tears
  - In children, usually not associated with intraarticular pathology or joint effusion
    - Possibly related to unrecognized trauma or congenital predisposition
    - Frequently bilateral
- Slit-like capsular opening into gastrocnemius-semimembranosus bursa (Baker cyst) behind posterior horn of medial meniscus
  - Slit = 15-20 mm vertically oriented opening
- Capsule unsupported at this location
  - Between expansions of semimembranosus tendon medially & posterior cruciate ligament laterally
- Slit present on cadaveric study in 50% of subjects > 50 years age
  - Prevalence increases with age
  - Probably due to degenerative thinning of joint capsule
- Synovial fluid extruded through slit into bursa (cyst)
- Wall of bursa composed of fibrous tissue lined by synovium
  - Synovium of bursa in continuity with synovium of knee joint
- Synovial disorders of knee also affect Baker cyst
  - Synovitis, synovial osteochondromatosis, pigmented villonodular synovitis (PVNS)
  - Infected cysts (uncommon)
- Other mechanisms whereby Baker cysts may potentially develop
  - Accumulation of fluid within noncommunicating gastrocnemius-semimembranosus bursa
  - Herniation of posterior joint capsule due to increased intraarticular pressure

Gross Pathologic & Surgical Features
- Fluid-filled bursal sac in popliteal space

Microscopic Features
- Lined by synovium, similar to knee joint

CLINICAL ISSUES

Presentation
- Most common signs/symptoms
  - Painless mass on medial side of popliteal fossa
  - Symptoms from underlying internal derangement (meniscal tear, osteoarthritis, chondral defect, etc.)
- Other signs/symptoms
  - Sudden onset of calf pain due to
    - Expansion of cyst
    - Leakage/rupture of cyst
    - Bleeding into cyst
  - Anticoagulation for clinically suspected deep venous thrombosis may aggravate bleeding or induce calf hematoma in cyst rupture
  - Symptoms from pressure on popliteal artery, vein, or tibial nerve are uncommon

Demographics
- Age
  - Prevalence increases with age
- Gender
  - More common in males
- Epidemiology
  - Most commonly encountered cyst around knee
    - ~ 15% of general population
    - 5% of pediatric MR knee studies
    - 15% of asymptomatic MR knee studies
    - 50% of elderly MR knee studies

Natural History & Prognosis
- Cyst may regress or enlarge
  - Overall good prognosis, especially in children
- In children, if cysts are treated conservatively, ~ 1/2 disappear & ~ 1/2 regress

Treatment
- Conservative
  - Treatment of associated internal derangement
  - Nonsteroidal anti-inflammatory agents, ice, assisted weight-bearing
  - Cyst aspiration ± intracystic steroid injection
    - High rate of recurrence
    - Occasionally, contents are too viscous to aspirate
    - Usually not possible on ultrasound to ascertain level of viscosity prior to aspiration
    - Intracystic steroid injection is indicated particularly for inflammatory component within cyst (inflammatory-type exudate, thick walled, hyperemia)
  - Trial of conservative treatment is optimal in children
- Surgical
  - Excision ± closure of joint-bursal communication
    - Recurrence is common

DIAGNOSTIC CHECKLIST

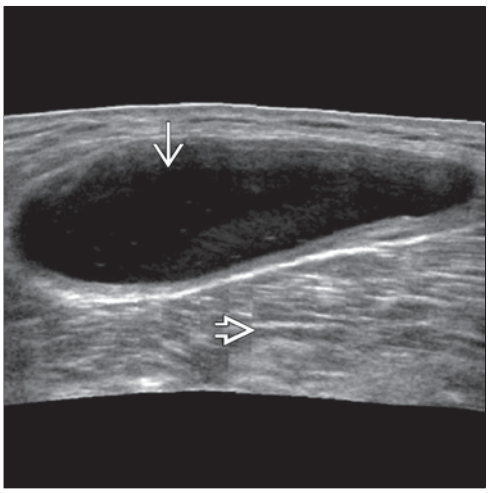
Consider
- Intraarticular pathology as this is very frequently associated with Baker cysts in adults
- Cyst content often mirrors content of knee joint

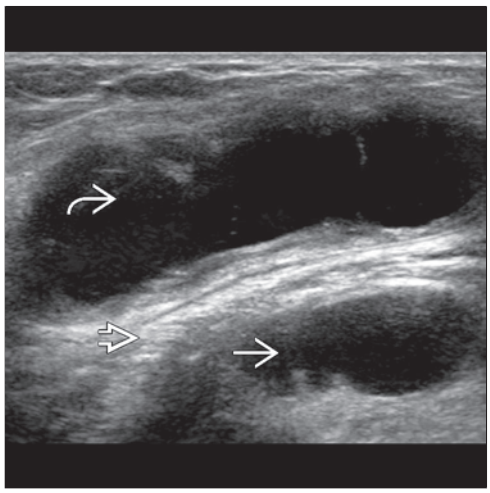
Image Interpretation Pearls
- Look for characteristic "talk-bubble" configuration of cyst on transverse imaging

SELECTED REFERENCES

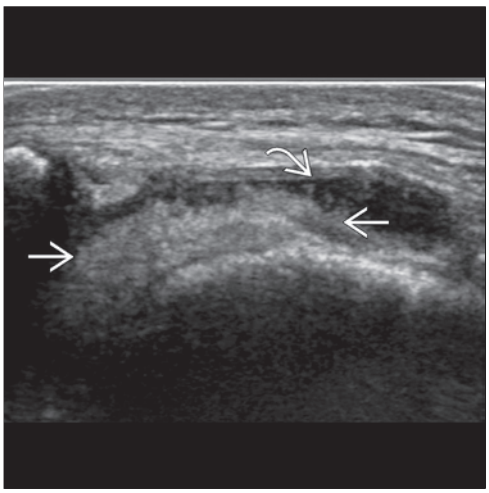
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2. Torreggiani WC et al: The imaging spectrum of Baker's (Popliteal) cysts. Clin Radiol. 57(8):681-91, 2002

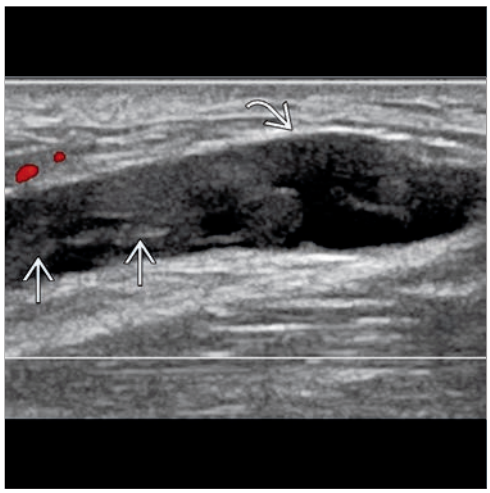
BAKER CYST



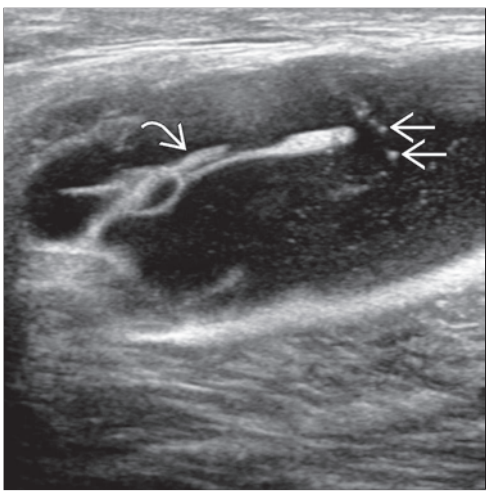


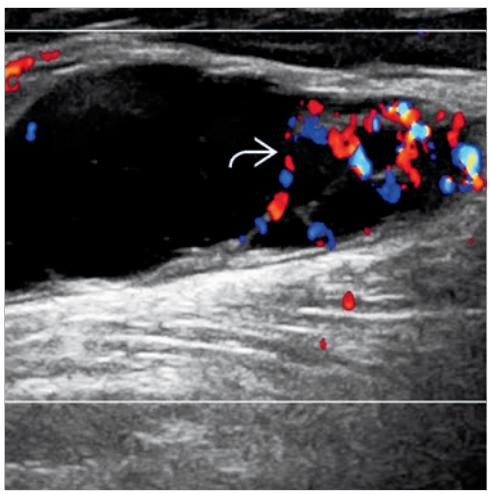
(Left) *Extended field-of-view ultrasound shows a thin-walled unilocular Baker cyst* ➔ *lying superficial to the medial belly of the gastrocnemius muscle* ➔. ***(Right)*** *Longitudinal ultrasound shows a Baker cyst extending distally in the calf both superficial* ➔ *and deep* ➔ *to the medial belly of the gastrocnemius muscle* ➔. *Most cysts just extend superficial to the gastrocnemius muscle.*





(Left) *Longitudinal ultrasound of the lateral patellar recess* ➔ *shows synovial proliferation* ➔ *in this patient with moderate inflammatory component to the associated knee osteoarthritis.* ***(Right)*** *Longitudinal color Doppler ultrasound of same patient shows synovial proliferation* ➔ *within the Baker cyst* ➔. *However, there is no demonstrable intracystic hyperemia. Inflammation within the knee will extend to a Baker cyst.*

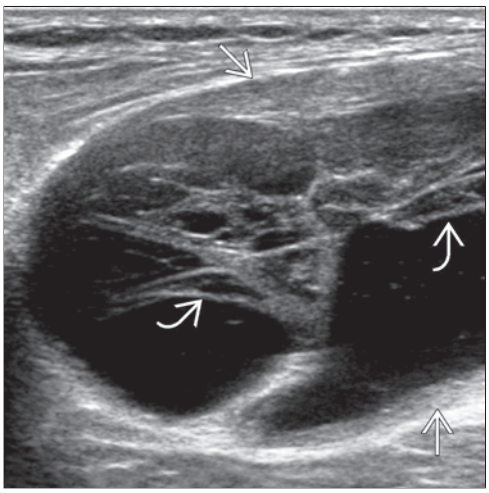


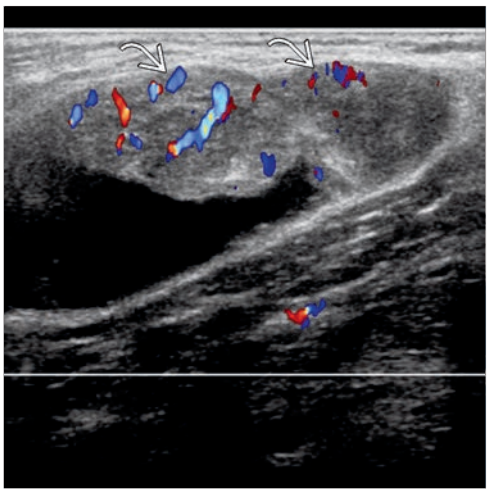


(Left) *Longitudinal ultrasound shows a Baker cyst containing thick synovial fronds* ➔ *and "comet tail" artifacts* ➔. *These "comet tail" artifacts are due to colloid aggregates.* ***(Right)*** *Longitudinal color Doppler ultrasound of the same patient shows marked hyperemia* ➔ *of the hypertrophied synovial fronds.*

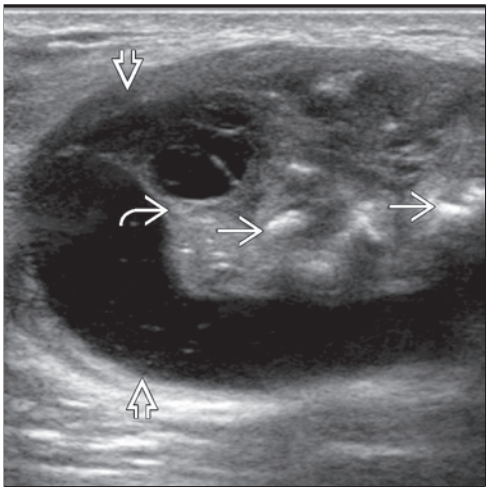
BAKER CYST

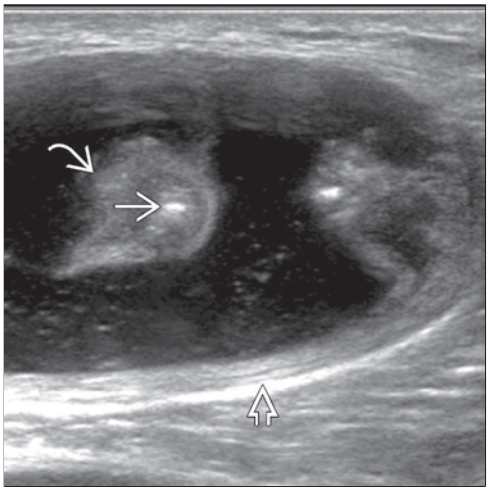
(Left) *Transverse ultrasound shows a thick-walled Baker cyst* ➔ *with fibrinous stranding* ➔ *and thick fibrous-type exudate.* ***(Right)*** *Longitudinal color Doppler ultrasound shows moderate hypervascularity* ➔ *within mass-like synovial proliferation in a patient with an inflammatory arthropathy of the knee joint. One should relate the appearances seen in a Baker cyst to those seen in the knee joint.*



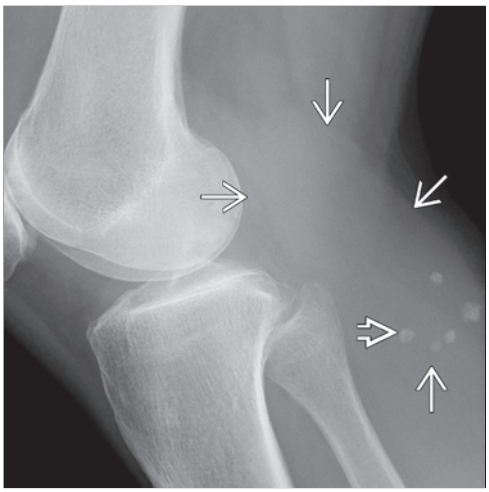


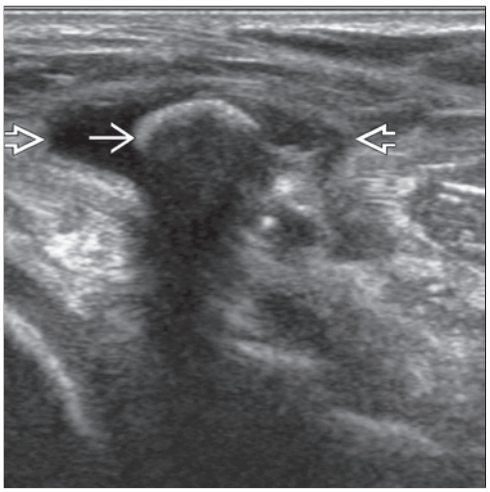
(Left) *Transverse ultrasound of a Baker cyst* ➔ *shows small areas of calcified debris* ➔ *within hypertrophied synovium* ➔. ***(Right)*** *Transverse ultrasound of the same patient shows calcified areas* ➔ *within the hypertrophied synovium* ➔ *of a thick-walled* ➔ *Baker cyst.*



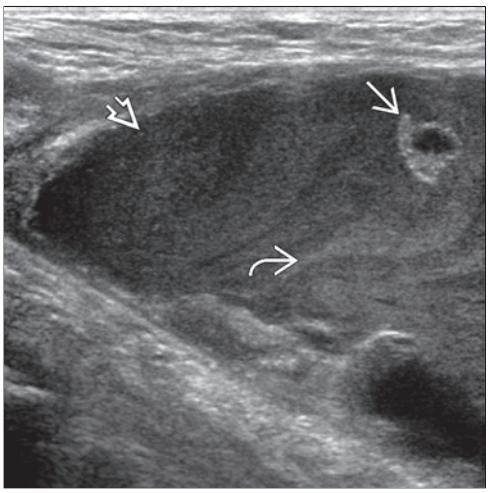


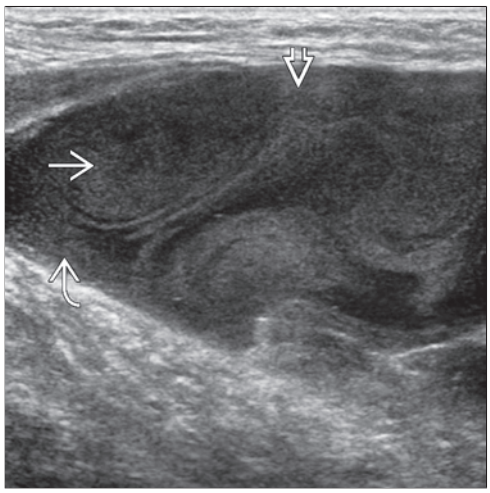
(Left) *Lateral radiograph of a knee shows soft tissue swelling* ➔ *of a Baker cyst containing small amounts of calcified debris* ➔. ***(Right)*** *Transverse ultrasound of the same patient shows a calcified fragment* ➔ *within part of the Baker cyst* ➔. *Osseous fragments within the knee joint can extend into a Baker cyst. Osseous fragments may also enlarge within Baker cysts.*



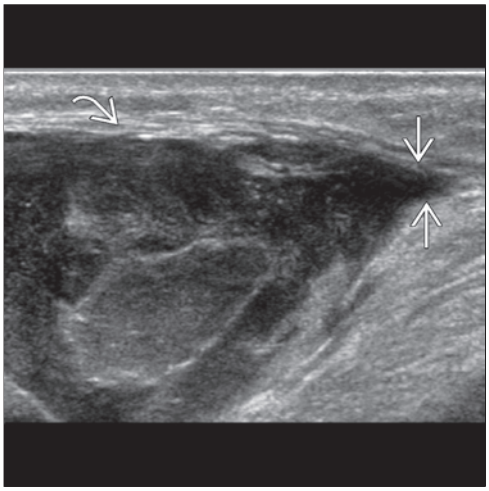


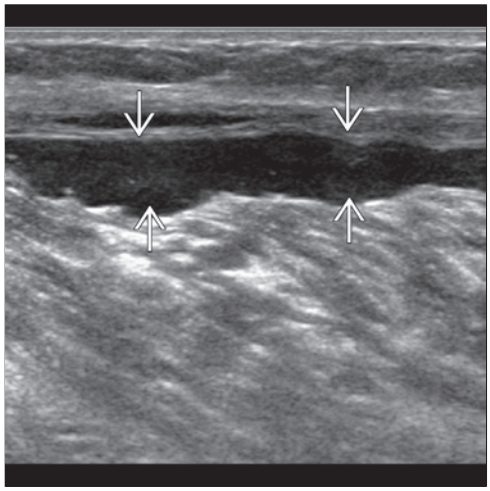
BAKER CYST



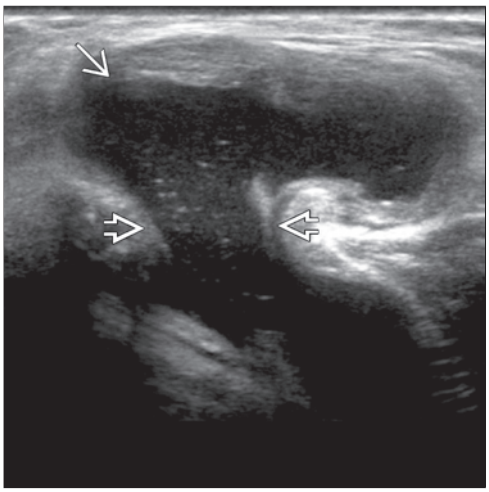


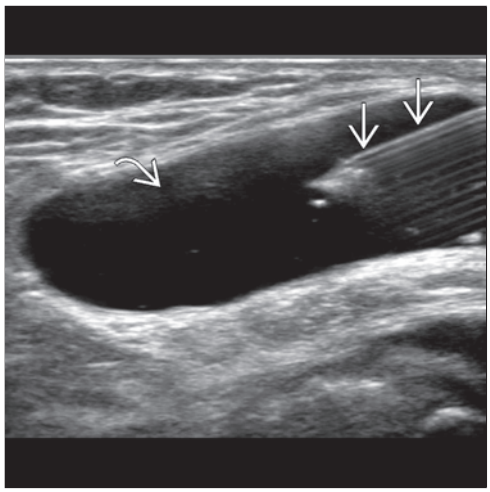
(Left) *Transverse ultrasound shows recent hemorrhage within a Baker cyst with finely speckled echogenic fluid. The small hyperechoic ring may be due to a detached synovial fragment.* ***(Right)*** *Transverse ultrasound of the same patient shows recent hemorrhage into the Baker cyst with echogenic fluid and early clot formation within the cyst.*





(Left) *Longitudinal ultrasound with extended field-of-view shows localized cyst leakage as evidenced by a sharp contour to the edge of the Baker cyst and lack of a discernible wall around the extracystic free fluid. Localized fluid leakage is much more common than frank cyst rupture.* ***(Right)*** *Longitudinal ultrasound of the same patient shows leaked fluid tracking more distally superficial to the medial belly of the gastrocnemius muscle.*





(Left) *Transverse ultrasound shows a Baker cyst with an unusually wide neck.* ***(Right)*** *Longitudinal ultrasound shows percutaneous aspiration with needle within a Baker cyst. There is some reverberation artifact deep to the needle. It is difficult to determine the viscosity of Baker cyst contents prior to aspiration. Also since most Bakers cysts tend to reaccumulate following aspiration, only temporary relief of symptoms is obtained.*

BURSITIS

Key Facts

Terminology
- Bursitis: Inflammation of lining of bursa

Imaging
- Majority of bursae are not visible on ultrasound unless distended with fluid or proliferative synovial tissue
- Acute bursitis: Thin-walled bursa distended with hypoechoic fluid, peribursal hyperemia
- Chronic bursitis: Greater thickening of bursal wall, more mature synovial proliferation, more echogenic content, & increased likelihood of intrabursal hyperemia
  - Can simulate soft tissue mass or abscess
  - If echogenic foci in distended bursa, consider crystal deposition
- Most bursae are accessible to ultrasound examination
  - ↓ transducer pressure to avoid effacement of superficial bursae
  - Ultrasound-guided aspiration ± injection
  - Aspiration (for cell count, crystals, gram stain, & culture including fungal, TB culture)

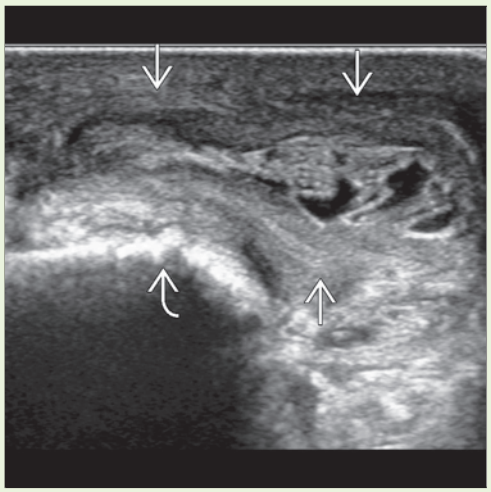
Top Differential Diagnoses
- Tendinosis & tendon tear

Clinical Issues
- Rest; anti-inflammatory agents
- Ultrasound-guided corticosteroids ± long-acting local anesthetic injection
- Excision for resistant cases

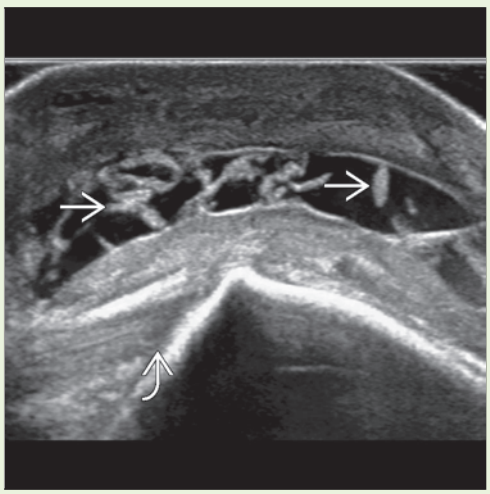
Diagnostic Checklist
- Small amount of fluid is normal in subacromial-subdeltoid bursa, deep infrapatellar bursa, & retrocalcaneal bursa
- Bursitis is common; infective bursitis is uncommon

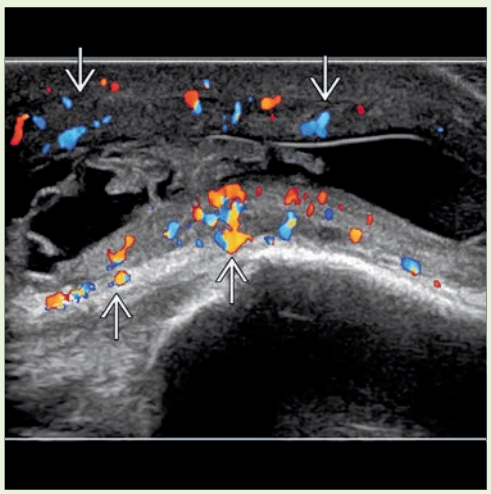
(Left) *Clinical photo shows a patient with posterior elbow swelling* ⇒ *that has been present for years but recently increased in pain and size.* ***(Right)*** *Transverse ultrasound shows a large olecranon bursitis with a moderately thickened bursal wall* ⇒*. The bursa is distended by fluid and synovial proliferation and overlies the olecranon process* ⇒*. Olecranon bursae frequently have a thickened wall, internal debris, and septa. A noninflamed olecranon bursa is not visible on ultrasound.*





(Left) *Longitudinal ultrasound of the same bursa shows the distended inflamed olecranon bursa with several thick internal septations* ⇒*, giving the bursa a multiloculated appearance. The normal triceps tendon insertion* ⇒ *into the olecranon process is shown.* ***(Right)*** *Longitudinal color Doppler ultrasound shows moderate hyperemia of the thickened bursal wall* ⇒ *and peribursal tissues. The internal content and septations show no hyperemia.*





BURSITIS

TERMINOLOGY

Synonyms

- Bursopathy, student's elbow (olecranon bursitis), ischial tuberosity (ischiogluteal) bursitis, trochanteric (hip) bursitis, prepatellar bursitis (housemaid's knee), infrapatellar bursitis (preacher's knee)

Definitions

- Bursitis: Inflammation of lining of bursa
  - Bursa: Synovial lined sac interspersed between tissues at areas of friction
  - 2 types of bursae
    - Synovial bursae: Constant synovial-lined bursae, which develop in utero in defined anatomical locations
    - Adventitious bursae: Non-synovial-lined bursae, which are acquired post partum due to friction between opposing tissues

IMAGING

General Features

- Best diagnostic clue
  - Fluid distended sac in typical location
- Location
  - Subacromial-subdeltoid bursa: Large bursa overlying rotator cuff tendons
    - Communicates with glenohumeral joint if full thickness tear of supraspinatus/infraspinatus tendons
  - Olecranon bursa: Overlies olecranon process & distal end of triceps tendon
  - Ischial tuberosity bursa: Between ischial tuberosity (hamstring tendon attachment) & gluteus maximus muscle
  - Iliopsoas bursa: Large bursa between iliopsoas tendon & anterior part of hip joint
    - Communicates with hip joint in 15% subjects
  - Trochanteric bursa: Laterally overlies gluteus medius & minimus tendon insertion into greater trochanter femur
  - Subgluteus minimus bursa: Between gluteus minimus tendon & anterior facet greater trochanter
  - Subgluteus medius bursa: Between gluteus medius tendon & posterosuperior facet greater trochanter
  - Semimembranous bursa: Posteromedial to semimembranous musculotendinous junction & tendon posteromedial aspect distal thigh
  - Pes anserine bursa: Between sartorius, gracilis, semitendinosus tendons, & posteromedial tibia
  - Prepatellar bursa: Overlies inferior pole of patella & proximal patellar tendon
  - Infrapatellar bursa: Overlies mid to distal aspect of patellar tendon
    - Do not confuse with deep infrapatellar bursa
      - Small amount of fluid in deep infrapatellar bursa is normal
  - Retrocalcaneal bursa: Between calcaneus, Achilles tendon, & Kager fat pad
    - Small amount of fluid in retrocalcaneal bursa is normal
    - No associated hyperemia normally
  - Superficial calcaneal bursitis: Overlies distal aspect of Achilles tendon
- Size
  - Few mm to several cm, depending on degree of bursal distension
- Morphology
  - Communicating or noncommunicating bursa
    - Communicating refers to bursa communicating with adjacent joint, e.g., iliopsoas bursa

Radiographic Findings

- Radiography
  - Soft tissue swelling

Ultrasonographic Findings

- General
  - Majority of bursae not visible on ultrasound unless distended with fluid or proliferative synovial tissue
  - Distended hypoechoic bursa
    - Thickened wall ± internal septation ± hemorrhage
  - Acute bursitis: Thin-walled bursa distended with hypoechoic fluid, peribursal hyperemia
  - Chronic cases: Greater thickening of bursal wall, more mature synovial proliferation, more echogenic content, & increased likelihood of intrabursal hyperemia
    - May simulate abscess or soft tissue mass
    - Especially for olecranon & ischiorectal bursa
- Subacromial-subdeltoid bursitis
  - Associated with tendinosis, tendon tears, & impingement
  - Fluid collects in dependent positions
    - Lateral aspect of greater tuberosity, over bicipital groove, near coracoid & deep to acromion
  - Bursal wall thickening & hyperemia are generally not a feature
    - If present, consider inflammatory arthropathy and check for rice bodies (uncommon)
- Olecranon bursitis
  - Common site for crystal deposition (echogenic foci within distended bursa)
- Ischial tuberosity bursitis: Large irregular bursa with moderate wall thickening ± internal septae ± debris
- Iliopsoas bursitis: Large bursa beneath musculotendinous portion of iliopsoas muscle, anterior to hip joint capsule
  - Communicates with hip joint 15%
  - Usually associated with hip arthropathy, e.g., inflammatory arthropathy or osteoarthritis
- Trochanteric bursitis: Uncommon
  - Most cases of trochanteric pain syndrome due to gluteus medius or minimus tendinosis or tears
- Semimembranous bursitis: May become inflamed due to impingement against osteophytes medial aspect tibial plateau
- Pes anserinus bursitis: Large distended bursa indented by 3 tendons (looks like goose's foot)
  - Prone to synovial proliferation
- Prepatellar bursitis: Often just subtle, hypoechoic, ill-defined band in prepatellar tissues
  - Usually due to repetitive trauma from kneeling (e.g., housemaid, carpet layer)
  - Occasionally infected (penetrating trauma)

BURSITIS

- Infrapatellar bursitis: Similar to prepatellar bursitis but located more distally
- Retrocalcaneal bursitis: Small amount of fluid in retrocalcaneal bursa is seen in 35% of normal subjects
  - Larger amount of fluid, bursal wall thickening, synovial proliferation, & peribursal or intrabursal hyperemia are indicative of bursitis
  - Nearly always associated with Achilles tendinosis

MR Findings

- T1WI
  - Homogeneous decreased signal intensity mass at typical location
- T2WI
  - Fluid-filled sac
  - ± inflammatory debris (isointense) or, less commonly, calcification (hypointense)
  - ± rice bodies (fibrin nodules, T1 & T2 hypointense)
- T1WI C+
  - ± immediate bursal wall enhancement with delayed enhancement of bursal content
  - Immediate intrabursal enhancement if synovial proliferation

Imaging Recommendations

- Best imaging tool
  - Ultrasound
  - Most bursae accessible to ultrasound
    - Facilitates ultrasound-guided aspiration or injection
- Protocol advice
  - High-resolution (> 10 MHz) linear transducer for superficial bursae
    - Lower resolution (~ 7 MHz) for deeper bursae
  - ↓ transducer pressure to avoid bursal effacement of superficial bursa
    - Use copious acoustic gel to lift transducer from skin
  - Transducer palpation or movement of part may allow fluid to be appreciated
  - Angulate transducer to minimize anisotropy & optimize tendon visibility
  - ± compare with opposite side
  - ± aspiration (for cell count, crystals, gram stain, & culture including fungal, TB culture)
  - Small amount of fluid in some bursae (deep infrapatellar, retrocalcaneal, subacromial-subdeltoid) may be normal
  - If subacromial-subdeltoid bursal fluid & no obvious rotator cuff tear, then pay particular attention to anterior leading edge of supraspinatus tendon for small avulsive-type tear

DIFFERENTIAL DIAGNOSIS

Tendinosis and Tendon Tear

- Insertional tendinosis commonly accompanies bursitis
  - Tendon thickening, hypoechogenicity, & loss of normal fibrillar pattern ± tendon tear
  - ± hyperemia & peritendinitis

PATHOLOGY

General Features

- Etiology
  - Chronic frictional trauma or overuse
  - Acute blunt trauma
  - Crystalline deposition (gout/pseudogout), especially in olecranon bursitis
  - Inflammatory joint disease
  - Infection (± penetrating trauma) is uncommon

Gross Pathologic & Surgical Features

- Bursal sac inflammation with variable synovial-like proliferation
  - Variable amount of fluid

Microscopic Features

- Thickened synovial lining with inflammatory reaction

CLINICAL ISSUES

Presentation

- Most common signs/symptoms
  - Pain ± mass
- Other signs/symptoms
  - Inflammation with warmth, tenderness, & redness
- Clinical profile
  - Overuse phenomenon

Demographics

- Age
  - Typically middle age
- Gender
  - Overall M = F
- Epidemiology
  - Common disorder, especially subacromial-subdeltoid bursitis and olecranon bursitis

Natural History & Prognosis

- Insidious onset
  - Typically resolves with cessation of aggravating activity or removal of aggravating factor

Treatment

- Conservative
  - Rest; anti-inflammatory agents
    - Ultrasound-guided corticosteroid ± long-acting local anesthetic injection
- Surgical
  - Excision for resistant cases

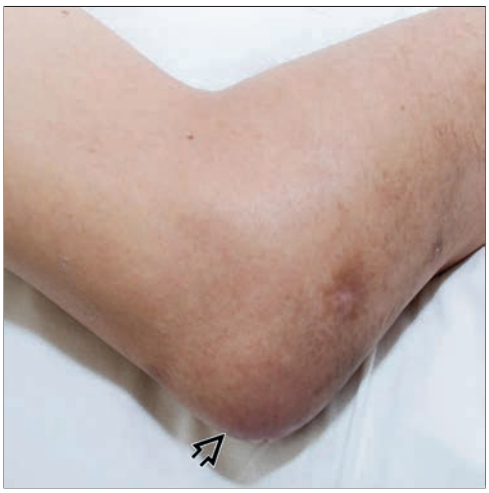
DIAGNOSTIC CHECKLIST

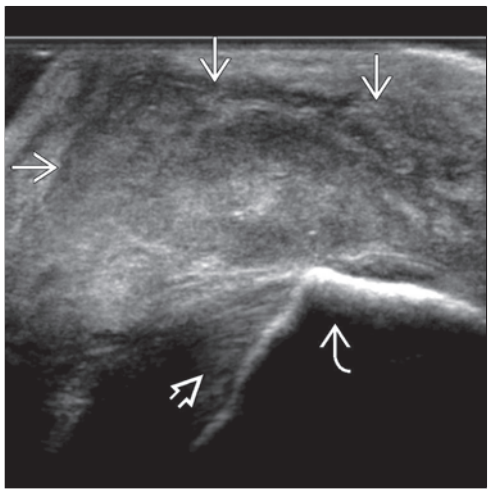
Consider

- Small amount of fluid is normal in subacromial-subdeltoid bursa, deep infrapatellar bursa, & retrocalcaneal bursa

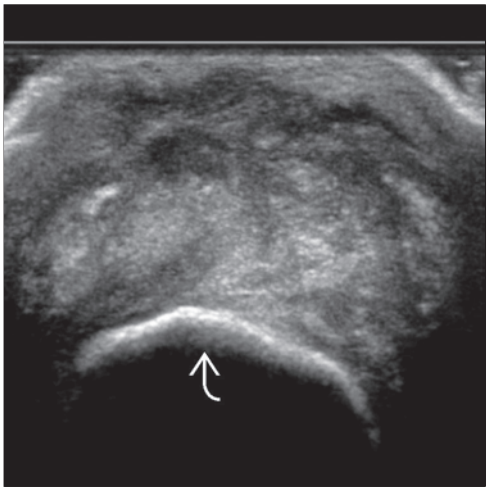
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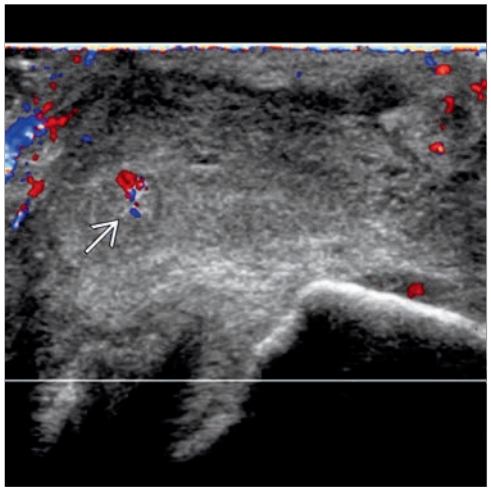
1. Daghir AA et al: Dynamic ultrasound of the subacromial-subdeltoid bursa in patients with shoulder impingement: a comparison with normal volunteers. Skeletal Radiol. 41(9):1047-53, 2012



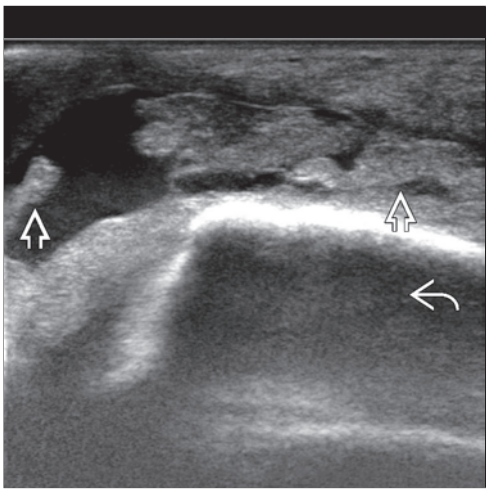


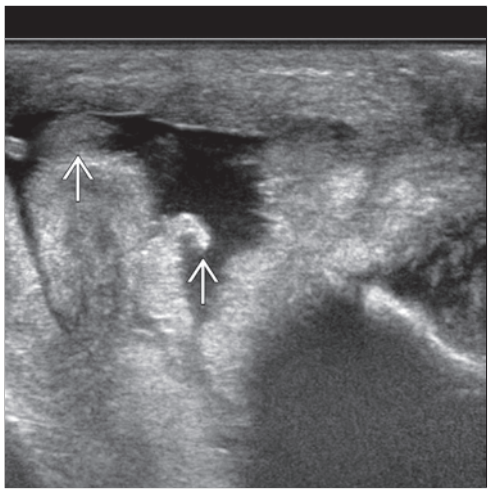
(Left) *Clinical photo shows a patient with posterior elbow swelling and pain for several months.* ***(Right)*** *Longitudinal ultrasound shows a large olecranon bursitis filled with chronic-type synovial proliferative tissue. The olecranon and triceps tendon are shown. This solid appearance is quite common for olecranon bursitis, which can still be diagnosed based largely on location and configuration. Biopsy rather than aspiration is usually more helpful in this solid-looking bursitis to determine likely etiology, if necessary.*





(Left) *Transverse ultrasound of the same bursa shows heterogeneous soft tissue within the distended olecranon bursa, located between the olecranon and the overlying skin.* ***(Right)*** *Transverse color Doppler ultrasound of the same bursa shows mild peribursal hyperemia. There is also mild hyperemia of the chronic-type synovial proliferation within the olecranon bursa. No percutaneous intervention was undertaken, as it was not likely to be helpful.*



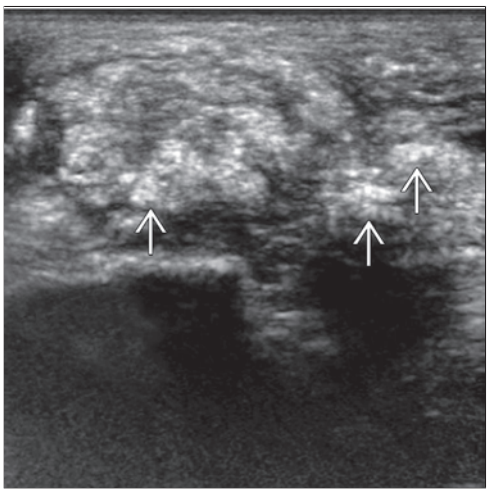


(Left) *Longitudinal ultrasound shows severe olecranon bursitis overlying the olecranon process. The distended bursa shows moderate synovial thickening with almost anechoic fluid.* ***(Right)*** *Transverse ultrasound of the same olecranon bursitis shows frond-like synovial proliferation within the distended bursa. Mild vascularity was present in the bursal wall on color Doppler imaging (not shown). The appearances are those of chronic olecranon bursitis.*

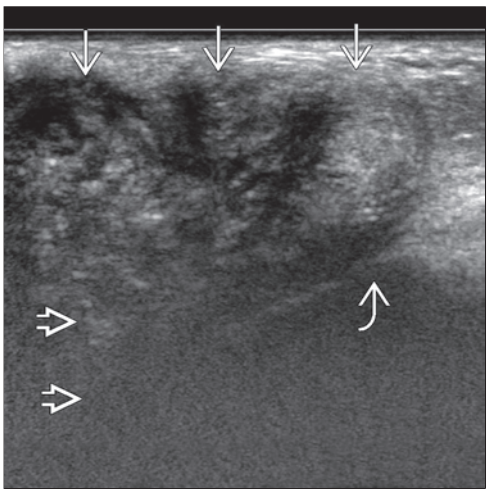
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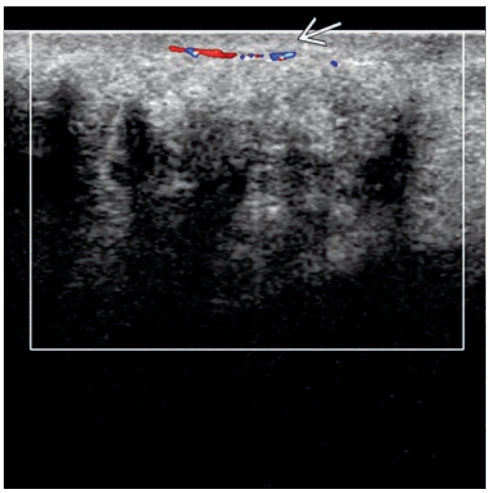
(Left) *Clinical photo shows a patient with elbow pain and swelling ⇨ present for 3-4 months.* ***(Right)*** *Transverse ultrasound of the same swelling shows an olecranon bursa distended with soft tissue containing many echogenic speckles consistent with calcified crystal aggregates ⇨. Features are compatible with chronic gouty olecranon bursitis. Chronic trauma, gout, and inflammatory arthropathy are common causes of aseptic bursitis.*



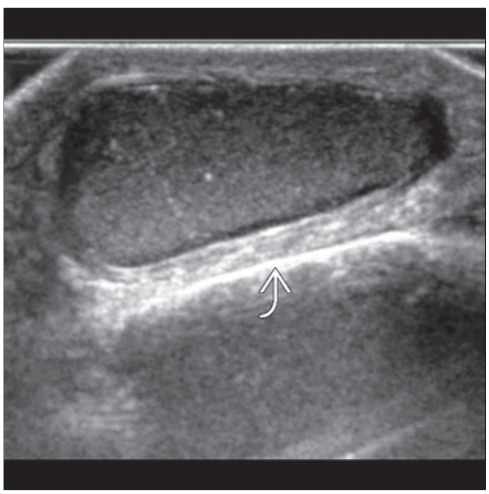


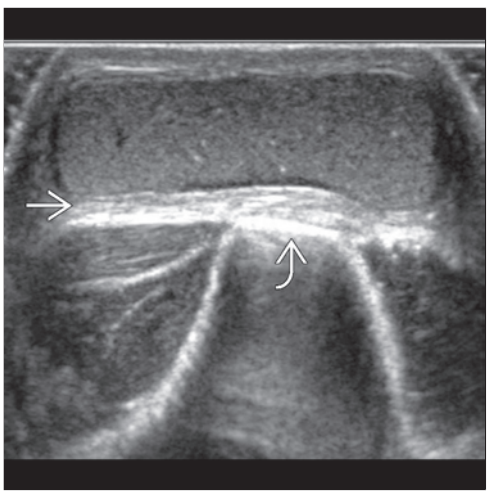
(Left) *Transverse ultrasound of the posterior elbow region shows a distended olecranon bursa ⇨ located between the olecranon ⇨ and the skin. The bursa is filled with proliferative synovium, with prominent posterior acoustic shadowing ⇨, a few small echogenic foci, and little demonstrable fluid. Features are compatible with chronic gouty olecranon bursitis.* ***(Right)*** *Transverse color Doppler ultrasound of the same bursa shows only mild marginal hyperemia ⇨.*

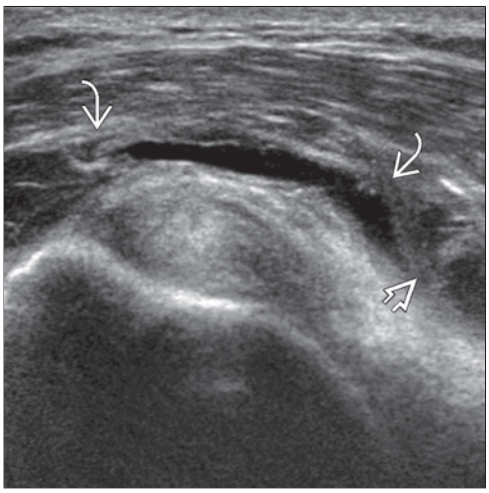


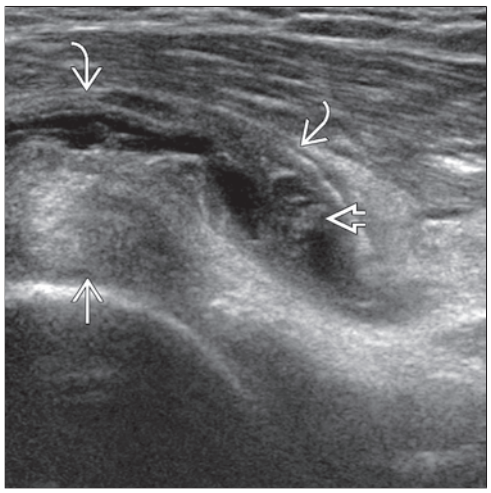


(Left) *Longitudinal oblique ultrasound shows a well-defined elbow mass located between the olecranon ⇨ and the skin, compatible with olecranon bursitis. The bursa is distended by fluid with low-level echoes suggestive of high proteinaceous or hemorrhagic content.* ***(Right)*** *Transverse ultrasound of the same bursa shows how the bursa lies superficial to the triceps tendon ⇨ and olecranon ⇨. One can appreciate the varied appearances of olecranon bursitis.*

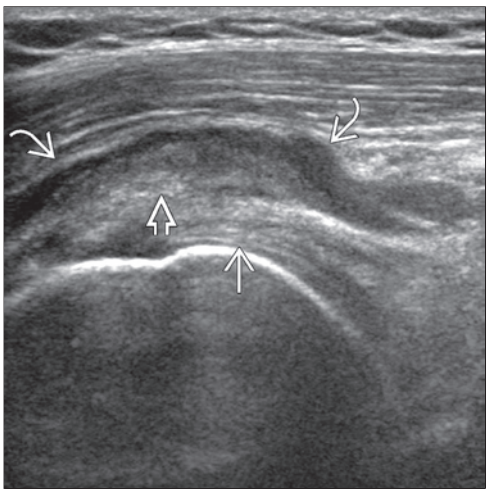


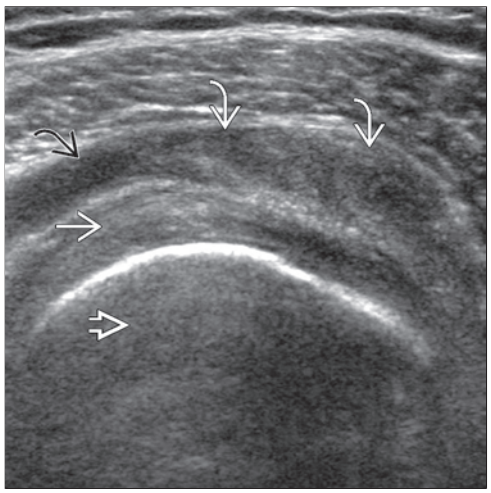




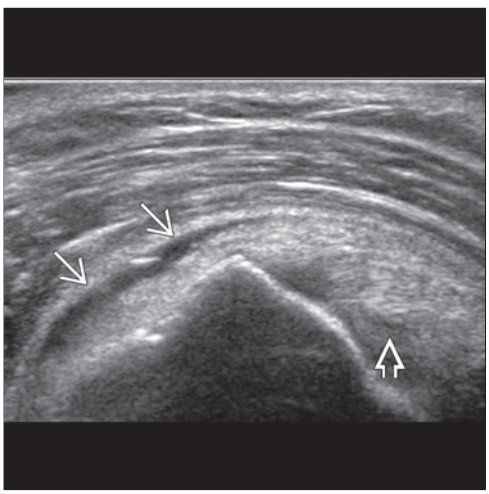


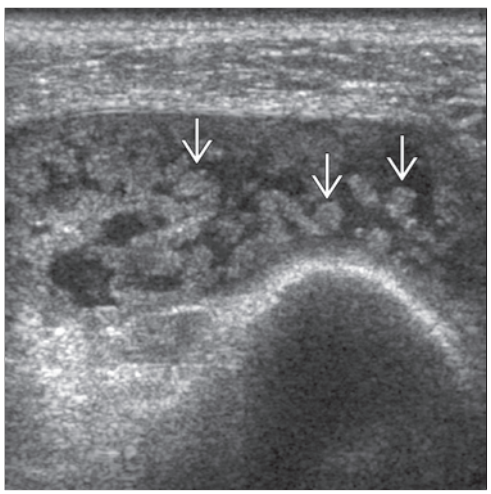
(Left) *Transverse ultrasound of a shoulder shows moderate chronic subacromial-subdeltoid bursitis. The bursa is distended by clear fluid and contains internal septae. There is moderate supraspinatus tendinosis.* ***(Right)*** *Longitudinal ultrasound of the same shoulder allows appreciation of the thickened subacromial-subdeltoid bursal wall with internal septation. Moderate tendinosis of the underlying supraspinatus tendon is present.*





(Left) *Longitudinal ultrasound of the shoulder shows a distended subacromial-subdeltoid bursa compatible with bursitis. There is prominent synovial proliferation. The underlying supraspinatus tendon is normal.* ***(Right)*** *Transverse ultrasound of the same shoulder shows the bursa distended by proliferative synovium and mildly echogenic fluid, consistent with chronic bursitis. The underlying supraspinatus tendon is intact overlying the humeral head.*

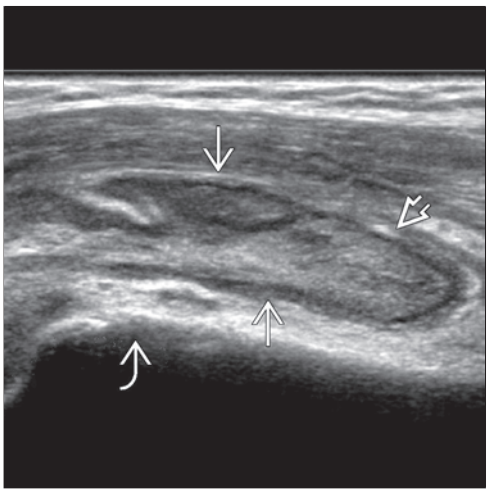


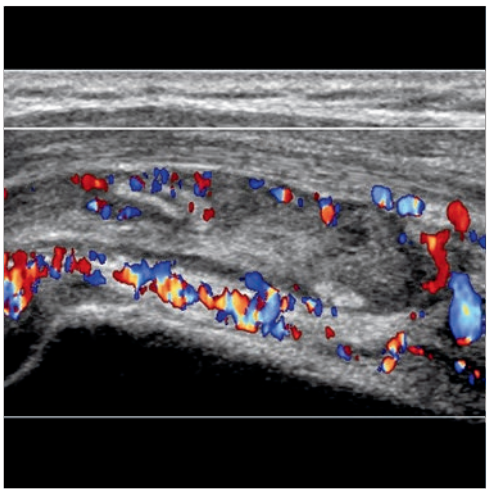


(Left) *Longitudinal ultrasound shows a small amount of fluid within the subacromial-subdeltoid bursa, consistent with mild bursitis. Mild supraspinatus tendinosis is present. No tendon tear was present.* ***(Right)*** *Transverse ultrasound of the proximal arm in a patient with rheumatoid arthritis shows the subacromial-subdeltoid bursa distended with multiple rice bodies. Rice bodies are more common in inflammatory arthropathy and TB. They are composed of fibrin rather than cartilage.*

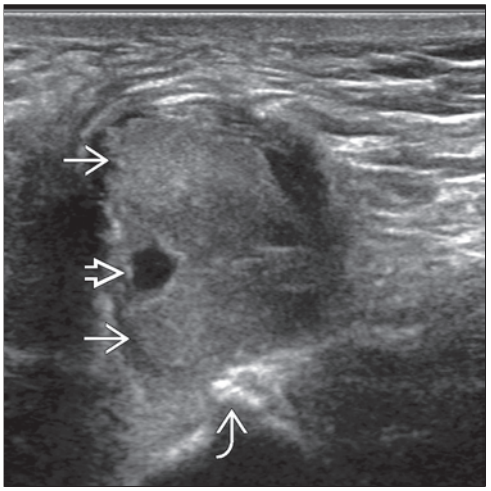
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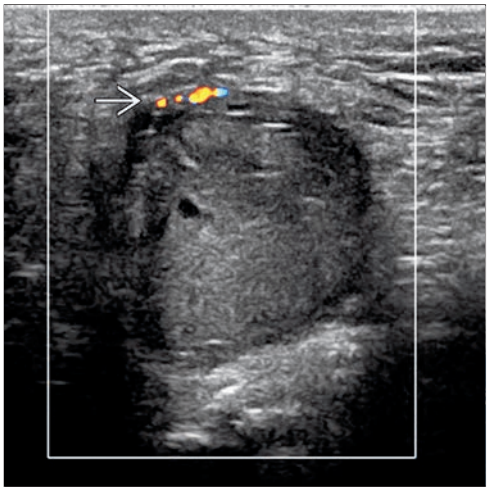
(Left) *Longitudinal ultrasound of a shoulder shows subacromial-subdeltoid bursa distended by heterogeneous echogenic tissue. The wall of the bursa is moderately thickened. The humerus is shown.* ***(Right)*** *Longitudinal color Doppler ultrasound of the same area shows severe peripheral hyperemia. Fine-needle aspiration yielded purulent fluid compatible with infective bursitis.*



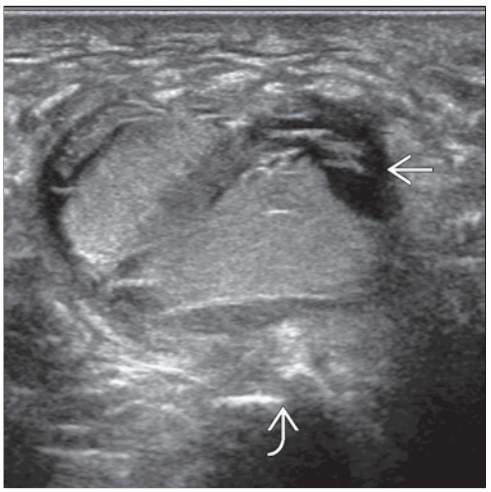


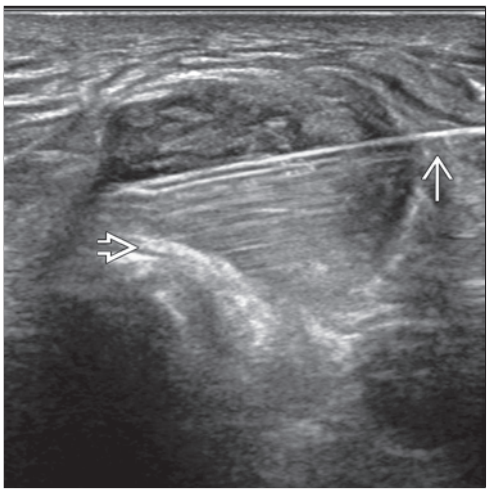
(Left) *Transverse ultrasound of the buttock shows ischial bursitis with a rather solid mass-like loculated lesion overlying the ischial tuberosity with small anechoic pockets of fluid.* ***(Right)*** *Transverse color Doppler ultrasound of the same mass shows only mild peripheral vascularity with no internal hyperemia. This is a fairly typical finding in inflammatory or infective bursitis.*

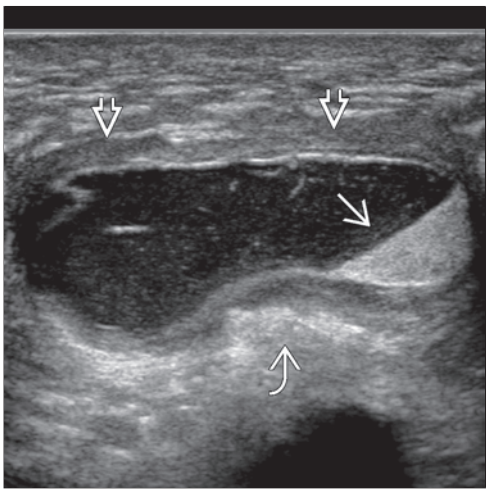


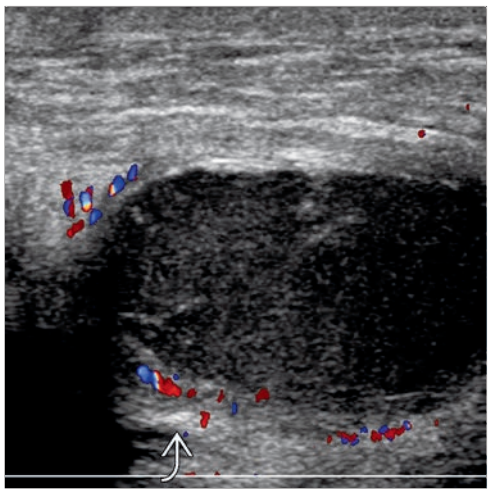


(Left) *Transverse ultrasound of the same mass a few minutes later shows more clearly the fluid component to the mass overlying the ischial tuberosity, consistent with ischial bursitis. Moderate surrounding soft tissue edema is present.* ***(Right)*** *Transverse ultrasound shows the same mass during fine-needle aspiration. Aspiration is used to relieve bursal pressure and rule out an infective or gouty etiology. Reverberation artifact is present from the needle.*

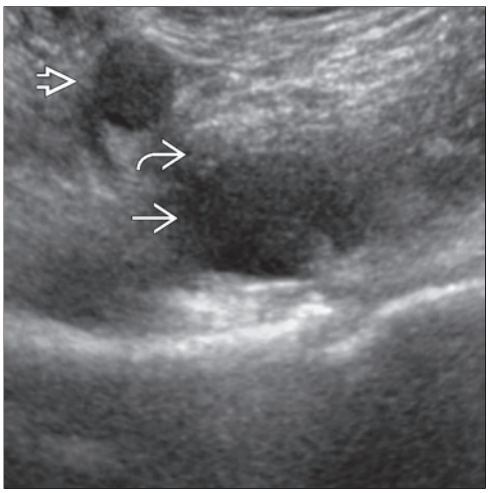


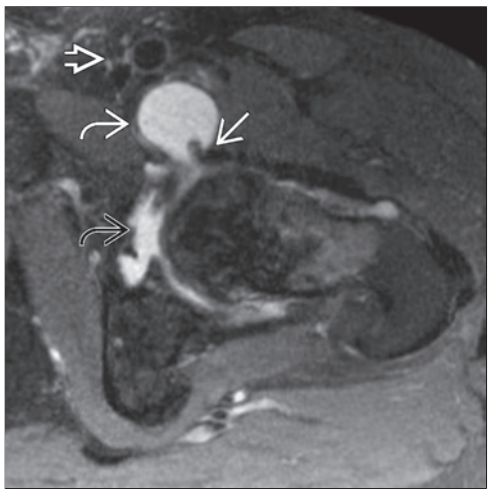




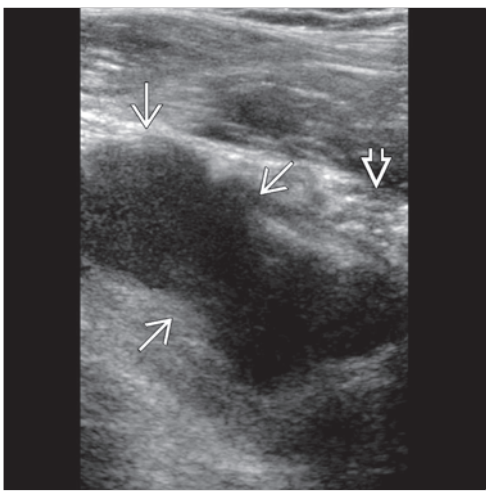


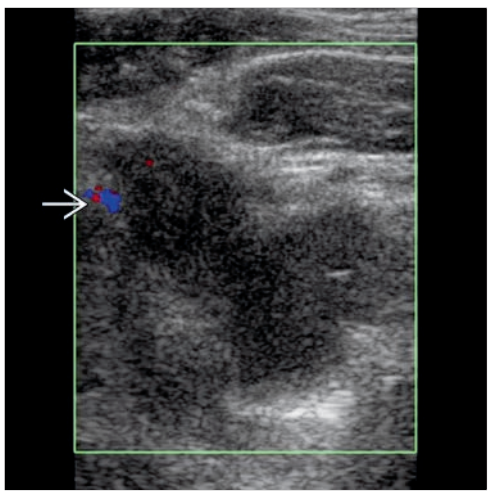
(Left) *Transverse ultrasound of the buttock shows a thick-walled chronic ischial bursitis overlying the ischial tuberosity. There is a fine debris within the bursa, forming a fluid-fluid level.* ***(Right)*** *Transverse color Doppler ultrasound of another patient shows severe ischial bursitis located superficial to the ischial tuberosity with mild marginal hyperemia consistent with chronic bursitis. The bursa is distended with echogenic fluid due to either hemorrhage or chronic inflammation.*





(Left) *Transverse ultrasound of the anterior hip region shows a fluid-distended bursa alongside the iliopsoas tendon. Note the anteriorly located common femoral artery.* ***(Right)*** *Axial T2WI FS MR of the same patient shows moderate iliopsoas bursal distension, which communicates via a short tract with the underlying joint. The adjacent iliopsoas tendon and common femoral vessels are shown.*

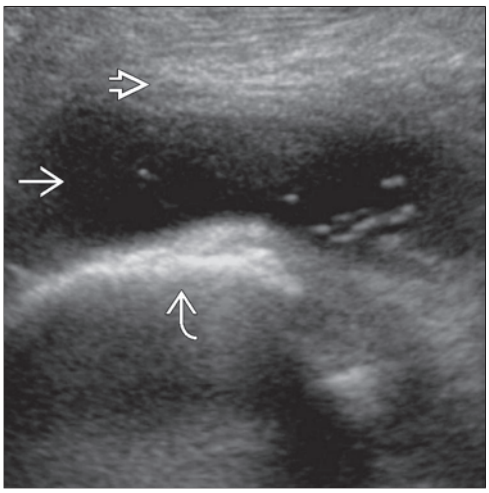


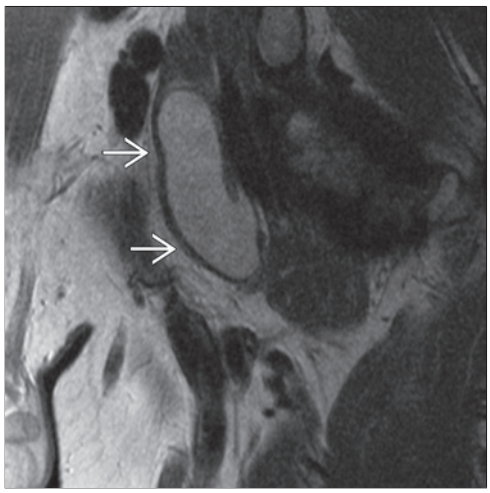


(Left) *Transverse ultrasound of the groin region shows a moderate-sized fluid collection located just deep to the iliopsoas musculotendinous junction and tendon. This is compatible with a distended iliopsoas bursa.* ***(Right)*** *Transverse color Doppler ultrasound of the same region shows mild hyperemia at the periphery of the distended bursa. Iliopsoas bursitis is associated with hip joint pathology (mostly osteoarthritis) and snapping hip syndrome.*

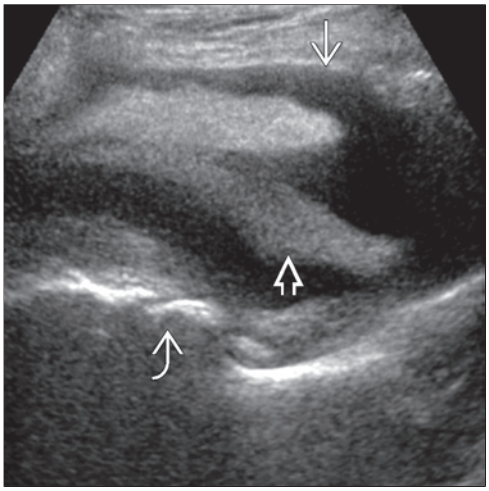
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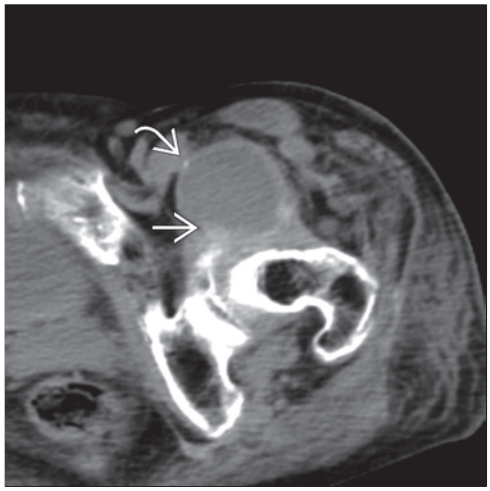
(Left) *Transverse ultrasound of the hip region shows moderate iliopsoas bursal distension anterior to the lesser trochanter. Note that the iliopsoas tendon is superficial to the bursal fluid.* ***(Right)*** *Coronal PDWI MR of the same patient shows a moderately distended iliopsoas bursa adjacent to the iliopsoas tendon. The bursal wall is better appreciated on MR imaging.*





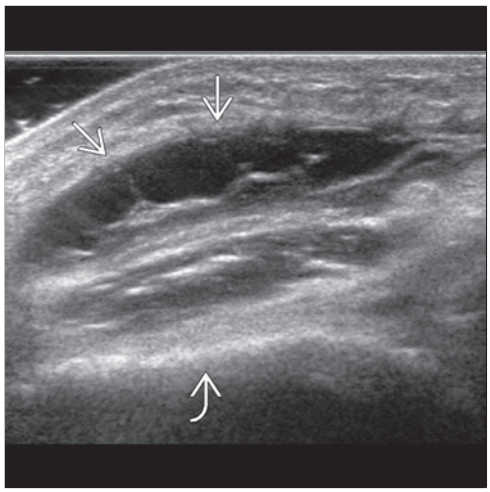
(Left) *Longitudinal ultrasound of the hip shows a large distended iliopsoas bursa superficial to the femoral head. The echogenic strands within the bursa are due to clotted blood. The iliopsoas tendon is not visible on this image.* ***(Right)*** *Axial NECT of the corresponding level in the same patient as previous image shows the distended bursa with clear fluid at the iliopsoas bursa. A small fleck of calcification is present in the bursa wall. The iliopsoas tendon is at the inferomedial aspect of the bursa.*

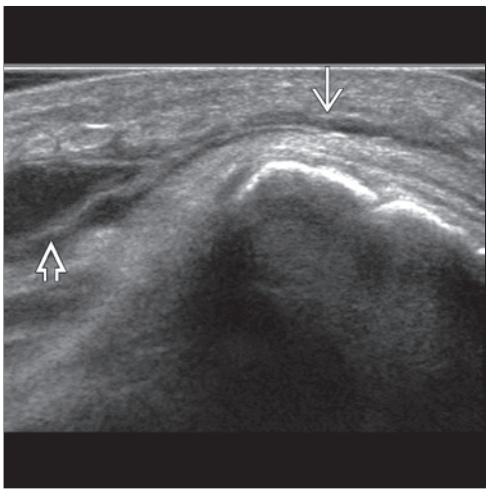


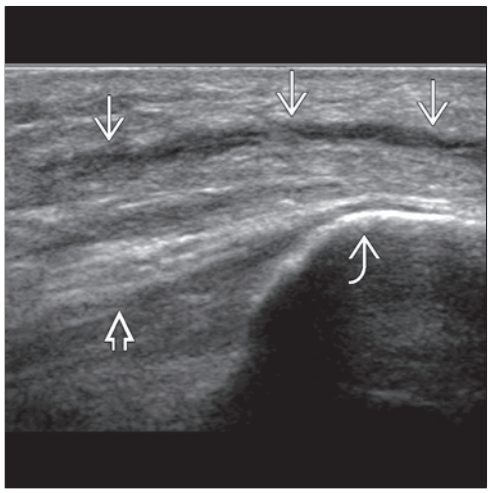


(Left) *Clinical photo shows a patient who had eccentric prepatellar swelling for 2 weeks.* ***(Right)*** *Longitudinal ultrasound of the prepatellar region shows a mild to moderate prepatellar bursitis superficial to the patellar bone. The bursa is distended with fluid, with some thin internal septae.*

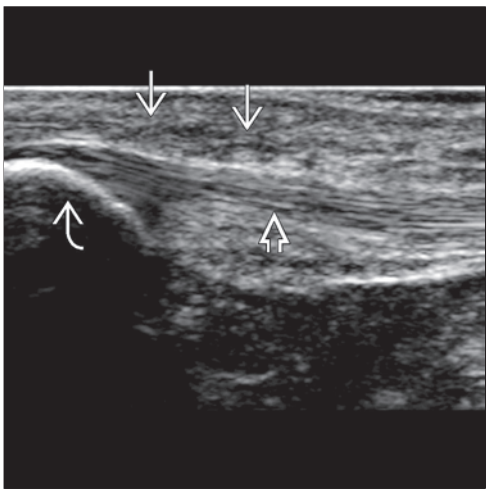


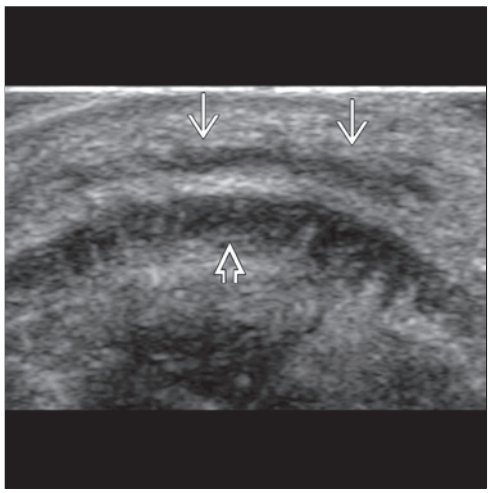




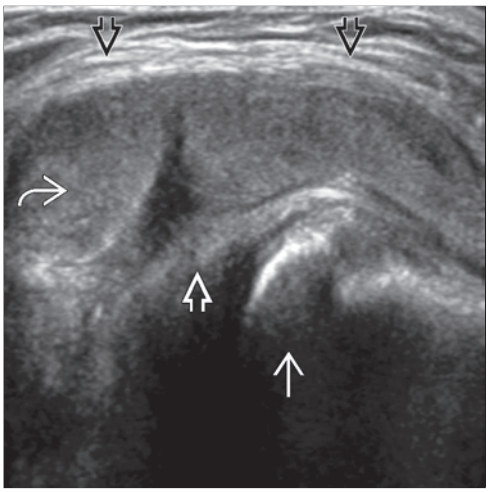


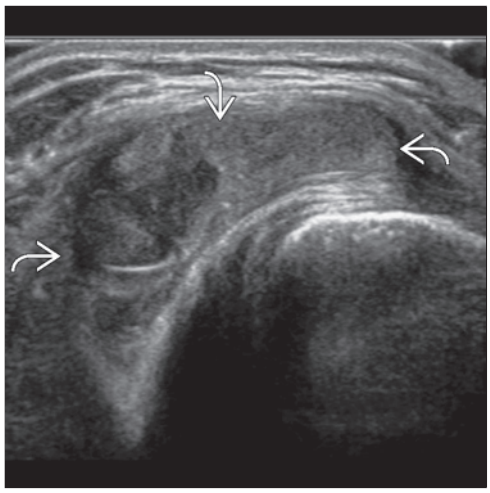
(Left) *Transverse ultrasound obtained more medial to the previous image shows the parapatellar collection* ➔ *communicating with a thin nondistended prepatellar bursitis* ➔. *Prepatellar bursitis is not just confined to the immediate prepatellar region.* ***(Right)*** *Longitudinal ultrasound of the same bursa shows the thin, hypoechoic prepatellar bursa* ➔ *located superficial to the patella* ➔ *and the proximal part of the patellar tendon* ➔.





(Left) *Longitudinal ultrasound of the knee shows a barely discernible thin bursitis* ➔ *located over the proximal part of the patellar tendon* ➔. *The patella* ➔ *is located just proximal to the bursitis.* ***(Right)*** *Transverse ultrasound of the same region shows more clearly the bursitis* ➔ *superficial to the patellar tendon* ➔. *This was termed an infrapatellar bursitis since it is located distal to the patella, though classical infrapatellar bursa is located more distal to this area.*

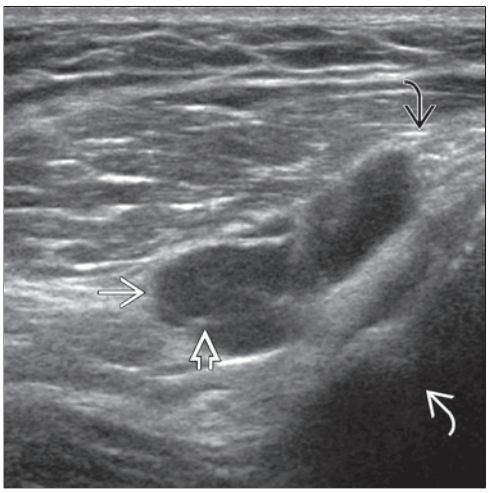


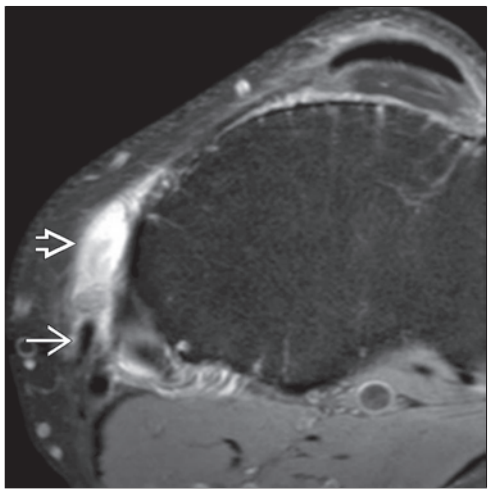


(Left) *Longitudinal oblique ultrasound of the knee just medial to the proximal tibia* ➔ *shows an echogenic fluid collection* ➔ *immediately superficial to the semitendinosus* ➔ *and deep to the sartorius tendon* ➔, *compatible with pes anserinus bursitis.* ***(Right)*** *Transverse ultrasound of the same pes anserinus bursa shows heterogeneous bursal fluid within the distended bursa* ➔. *The normal pes anserinus bursa is a potential space and cannot be visualized on ultrasound.*

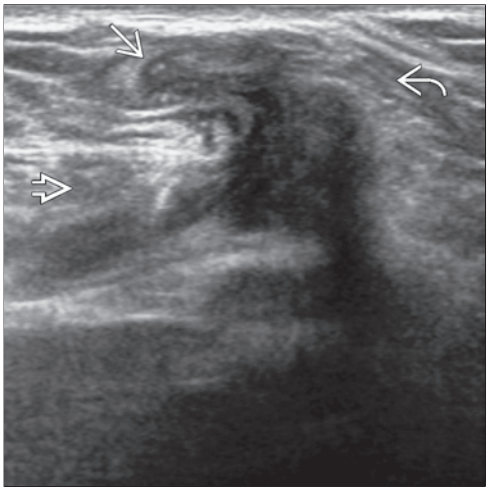
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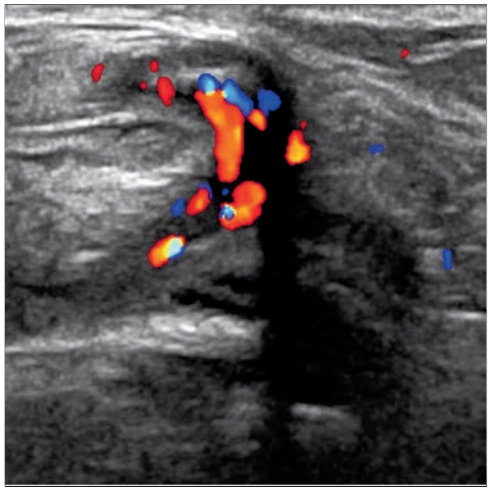
(Left) *Longitudinal oblique ultrasound of the knee close to the medial aspect of the proximal tibia shows a fluid collection with internal fibrous stranding immediately adjacent to the pes anserinus tendons compatible with a pes anserinus bursitis.* ***(Right)*** *Axial PD FSE FS MR of the same pes anserinus tendon bursitis shows a multiloculated cystic collection alongside the pes anserinus tendons.*





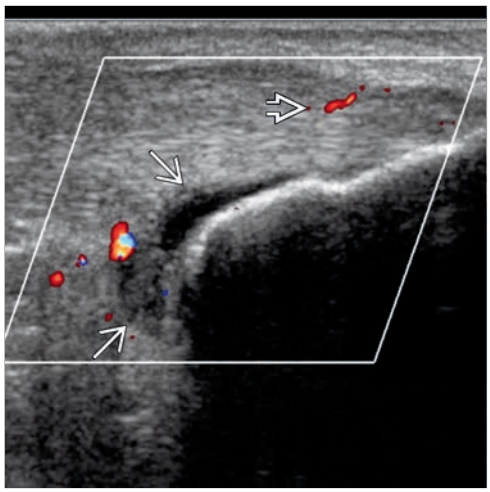
(Left) *Transverse ultrasound at the medial aspect of the popliteal fossa shows an irregular fluid collection between the medial belly of the gastrocnemius and the semitendinosus tendon, compatible with semitendinosus bursitis.* ***(Right)*** *Transverse color Doppler ultrasound of the same patient shows significant hyperemia of the peribursal soft tissues, consistent with acute inflammation.*

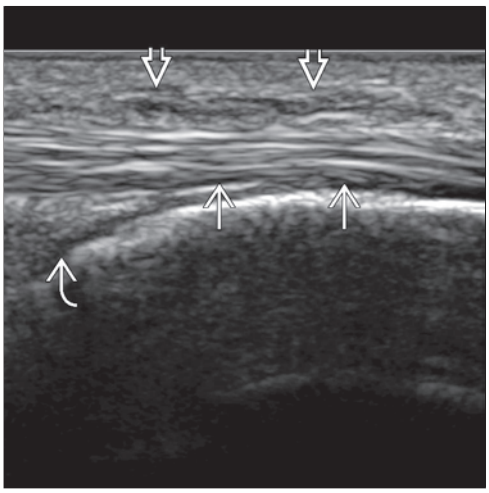


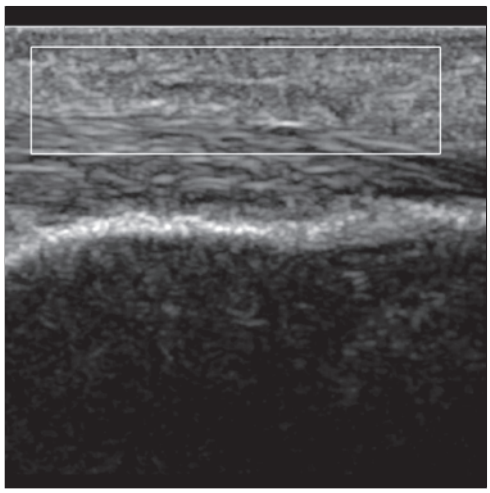


(Left) *Clinical photo shows a patient with a history of posterior ankle swelling, redness, and pain for 3 months.* ***(Right)*** *Longitudinal color Doppler ultrasound of the same area shows a mildly distended retrocalcaneal bursa with synovial proliferation and mild adjacent hyperemia. Mild distal Achilles tendinosis is present with mild hyperemia. Mild retrocalcaneal bursal distension is normal, but hyperemia and synovial proliferation are not normal features.*

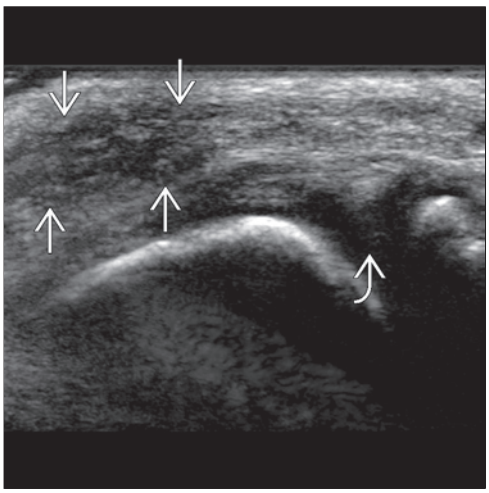


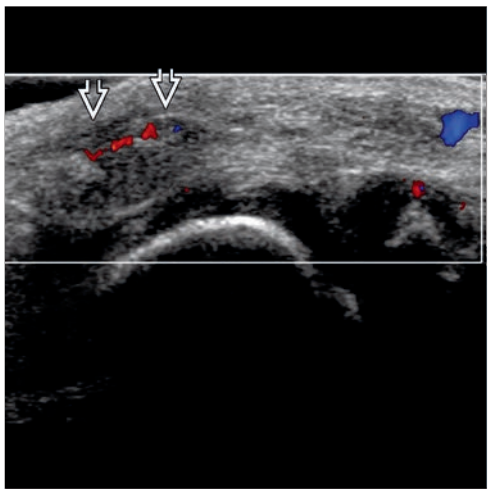




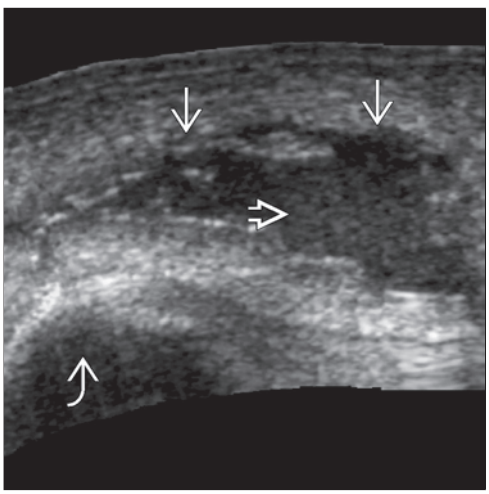


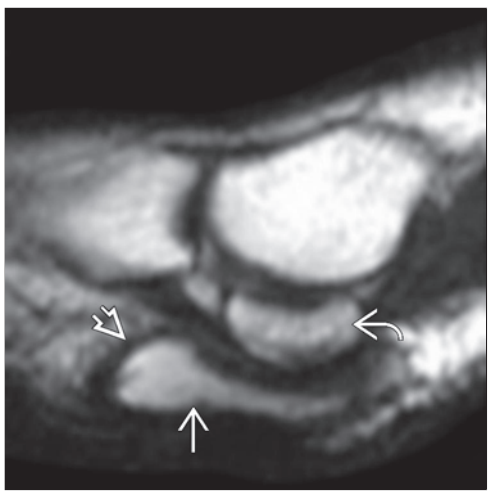
(Left) *Longitudinal ultrasound of the posterior heel shows a thin, mildly distended and thickened superficial calcaneal bursa just superficial to the Achilles tendon distally. The Achilles tendon is normal in appearance with no tendinosis. There is no abnormal fluid in the retrocalcaneal bursa to suggest bursitis.* ***(Right)*** *Longitudinal color Doppler ultrasound shows no significant hyperemia consistent with chronic low-grade bursitis. Superficial calcaneal bursitis is usually seen as a thin echogenic line.*





(Left) *Longitudinal ultrasound shows a patient with 1st metatarsophalangeal joint swelling and pain. There is a quite well-defined area of subcutaneous thickening superficial to the metatarsal head compatible with chronic bursitis.* ***(Right)*** *Longitudinal color Doppler ultrasound shows mild hyperemia at the corresponding site of the thickened bursa, indicative of active inflammation. Adventitious bursae may potentially develop under any of the metatarsal heads.*





(Left) *Longitudinal ultrasound of the plantar aspect of the 1st metatarsophalangeal joint region shows an irregularly distended bursa with fluid and debris overlying the medial sesamoid bone. Features are compatible with chronic bursitis.* ***(Right)*** *Sagittal PDWI MR of the same region shows the distended plantar bursa with a thickened wall overlying the medial sesamoid bone. The bursal content can be better appreciated on ultrasound than on MR.*

GANGLION CYST

Key Facts

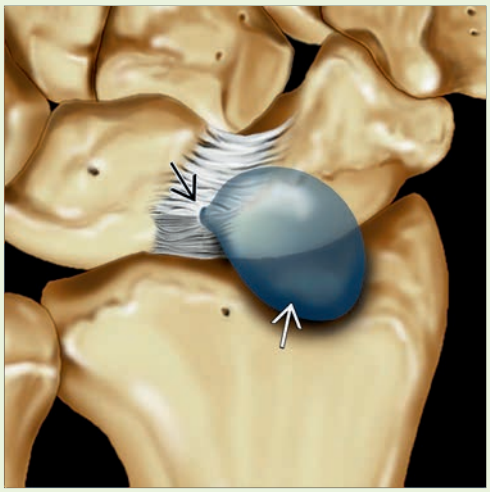
Imaging

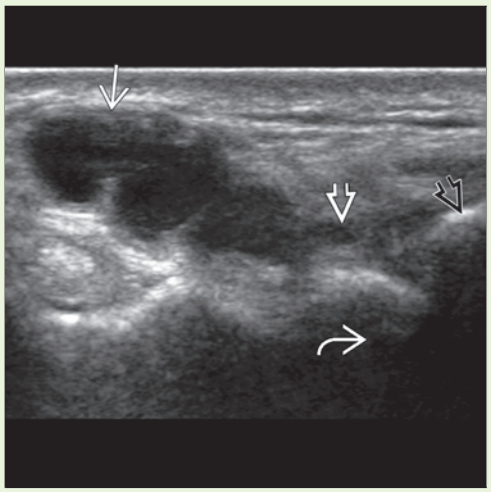
- Fluid-filled mass with stalk extending toward joint
- Ovoid or irregular configuration with stalk connecting to joint of origin
  - Elongated neck allows cyst to surface at distance from joint of origin
- Hypoechoic with clear fluid
  - ± septation
  - ± "comet tail" artifacts (due to colloid aggregates)
- Not compressible
- No hyperemia except with recent leakage when surrounding tissues may be mildly hyperemic and edematous
  - Leakage of ganglion contents induces soft tissue inflammation
- Ultrasound will allow diagnosis of most ganglion cysts
  - Multidirectional capability allows stalk to be traced toward joint
- Locate telltale stalk of cyst and trace it back toward joint of origin
- Evaluate with color Doppler to exclude vascular anomaly and nerve sheath tumor

Clinical Issues

- In adults, up to 50% of wrist ganglia will resolve without treatment within 6 years
- In children, > 90% ganglion cysts will resolve without treatment within 1 year
- Aspiration (ultrasound guided)
  - > 70% complete resolution for ganglia alongside flexor tendon sheath (retinacular ganglia)
  - < 50% complete resolution for other ganglia, though they may become smaller and less symptomatic (incomplete resolution)
  - Greater success if ganglion is present for < 1 year
- Surgical excision

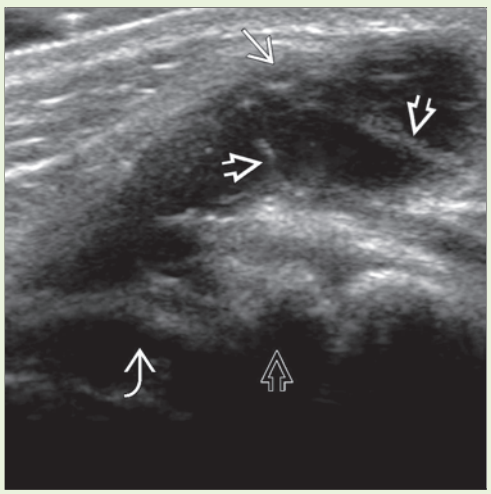
(Left) *Graphic shows the typical location of a dorsal wrist ganglion cyst* ➡ *arising from a defect in the dorsal capsule of the scapholunate ligament* ➡*. The ligament remains functionally intact.* ***(Right)*** *Oblique ultrasound shows a lobulated ganglion cyst* ➡ *in the dorsal aspect of the wrist. The stalk of the ganglion* ➡ *extends toward the articulation between the scaphoid* ➡ *and the distal radius* ➡*.*





(Left) *Clinical photograph of the wrist of a young patient shows dorsal swelling* ➡ *suggestive of a ganglion cyst.* ***(Right)*** *Oblique ultrasound of the same patient shows a ganglion* ➡ *arising from the dorsal aspect of the radioscaphoid articulation. There is mild septation* ➡ *within the ganglion. The radial epiphysis* ➡ *and scaphoid* ➡ *are shown. The small terminal branches of the posterior interosseous nerve, which may be compressed, are not easily visible on ultrasound.*





GANGLION CYST

TERMINOLOGY

Synonyms
- Bible bump, Gideon disease, digital mucous cyst

Definitions
- Ganglion: Myxoid tissue encased in a fibroblastic collagenous wall with no synovial lining
  - Occur in predictable locations
- Occult ganglion: Ganglion not clinically apparent

IMAGING

General Features
- Best diagnostic clue
  - Fluid-filled mass with stalk extending toward joint
- Location
  - Dorsal wrist ganglia
    - May compress terminal branch of posterior interosseous nerve, 1 branch of which lies near dorsal aspect scapholunate interval
    - Scapholunate joint
      - Typically emerge through or just distal to scapholunate ligament between 3rd and 4th extensor compartments
      - Most common type of dorsal wrist ganglion
      - Functionally intact scapholunate ligament
    - Also commonly arise from radioscaphoid joint, scaphotrapeziotrapezoid joint (triscaphe joint), and ulnocarpal joints
  - Volar wrist ganglia
    - Typically arise in weak spot between radioscaphocapitate and radiolunotriquetral ligaments (space of Poirier) overlying lunocapitate interval
    - Also arise from radioscaphoid joint, scaphotrapeziotrapezoid joint, ulnocarpal joints
    - Pisiform-triquetral joint
      - Can extend into Guyon canal and compress ulnar nerve
      - Do not confuse proximal (larger) or distal (smaller) pisotriquetral recesses with ganglia
  - Finger
    - Flexor tendon sheaths near A1 pulley or A2 pulley
    - Dorsal aspect of distal interphalangeal joint (digital mucous cyst)
  - Acromioclavicular joint
  - Shoulder
    - Posterosuperior, usually associated with labral tear
  - Lumbar facet joints (not usually demonstrable by US)
  - Hip
    - Anterosuperior, usually associated with labral tear
  - Knee
    - Anterior and posterior cruciate ligaments
    - Paraarticular, deep to supracondylar attachment of medial or lateral belly of gastrocnemius
  - Proximal tibiofibular joint
    - Articular branch of deep peroneal nerve explains propensity of ganglia from this joint to extend intraneurally
    - Ganglia may extend intraneurally into deep peroneal nerve, common peroneal nerve, or even peroneal division of sciatic nerve
  - Distal tibiofibular syndesmosis
  - Foot and ankle
    - Cuneonavicular joint, intercuneiform joint, subtalar joint, talonavicular joint
- Size
  - Average: 5 mm; ganglia from large joint may reach > 50 mm in maximum dimension
  - May increase with activity
- Morphology
  - Ovoid or irregular configuration with stalk connecting to joint of origin

Radiographic Findings
- Radiography
  - Usually normal
  - ± soft tissue density
  - ± intraosseous carpal ganglion

MR Findings
- T1WI
  - Hypointense to intermediate signal intensity mass
- T2WI
  - Uniformly hyperintense soft tissue cystic mass
  - Narrow stalk connecting cyst to joint
  - Distension of a capsular recess may simulate cyst
    - Capsular recesses occur in expected locations
    - Wide communication with joint cavity
    - If capsular recess is unusually distended for given amount of joint effusion, consider ganglion
    - Cysts often contain septations
- Very sensitive at detecting occult ganglia

Ultrasonographic Findings
- Well-defined, hypoechoic, fluid-filled mass with stalk extending toward joint
  - Typical location
  - Elongated neck allows cyst to surface at distance from joint of origin
  - ± multiloculated
  - ± thin septations
  - ± small "comet tail" artifacts due to colloid aggregates
  - ± inflammatory exudate: Inflammatory content of joint can extend into ganglia
  - Not compressible
  - No hyperemia except with recent leakage when surrounding tissues may be mildly hyperemic and edematous
    - Contents of ganglion cyst can induce short-lived inflammation of adjacent tissues
- Stalk may be thin and serpiginous
  - Locating entry site of stalk into joint will help surgical planning
- Ganglia close to A1 pulley have no visible communication with tendon sheath
- Hemorrhagic cyst: Can have pseudosolid appearance
  - Will change appearance on follow-up imaging
- Ruptured cyst
  - Collapsed cyst with pericystic inflammation

Imaging Recommendations
- Best imaging tool
  - Ultrasound allows diagnosis of most ganglion cysts
    - Allows stalk to be traced toward joint
- Protocol advice
  - Locate telltale stalk of cyst and trace it back toward joint of origin

GANGLION CYST

- Extension through joint capsule is often not seen
  - Examination of wrist in flexion ± extension may occasionally help
- Note important relationships of cyst (i.e., to tendons and neurovascular bundle)
- Evaluate with color Doppler to exclude vascular anomaly and nerve sheath tumor

DIFFERENTIAL DIAGNOSIS

Giant Cell Tumor of Tendon Sheath
- Soft tissue mass, usually hyperemic
- Eccentrically located to tendon sheath

Vascular Anomaly
- Compressible
- ± phleboliths, ± flow on color Doppler imaging
- Lymphangiomas may appear similar to ganglion cysts
  - Tend to occur in areas different from those of ganglia
  - Do not have stalk communicating with joint

Cystic Schwannoma
- Some nerve sheath tumors may be almost purely cystic
  - Generally occur at locations different from those of ganglia
  - Can see entering/exiting nerve

PATHOLOGY

General Features
- Etiology
  - Typical locations are due to capsular weakness or nerve traversing capsule
    - Degenerative or traumatic tear in capsule
      - Only 15% are related to specific injury
    - Joint fluid pumped 1 way between collagen bundles
    - Post-traumatic ganglia may develop acutely over a few hours to days
- Associated abnormalities
  - Intraosseous ganglia are more common in subjects with soft tissue ganglia
  - Single ganglion may simultaneously have both intraosseous and extracapsular components

Gross Pathologic & Surgical Features
- Cystic mucinous fluid is contained in pseudocapsule

Microscopic Features
- Capsular lining = compressed loose areolar tissue = pseudocapsule
- No inner cell lining
  - Not lined by synovial tissue

CLINICAL ISSUES

Presentation
- Most common signs/symptoms
  - Slowly growing soft tissue mass
- Clinical profile
  - Localized pain ± firm mass ± weakness
    - Typically pain on attempted full dorsiflexion of wrist (e.g., getting out of chair)
    - Cyst transilluminates
  - Neurologic findings with extension into carpal tunnel or Guyon canal and nerve compression (uncommon)

Demographics
- Age
  - 20-50 years
- Gender
  - M < F
- Epidemiology
  - 80% of all soft tissue masses of wrist and hand
    - 80% of wrist ganglia presenting clinically are on dorsal aspect
    - 80% of wrist ganglia overall occur on volar aspect (MR evidence)

Natural History & Prognosis
- In adults, up to 50% of wrist ganglia will resolve without treatment within 6 years
  - In children, > 90% of ganglion cysts will resolve without treatment within 1 year

Treatment
- Observe
  - Quite high rates of spontaneous resolution
- Active treatment
  - Indicated if cyst is painful or fails to resolve after 1 year, or if it is cosmetically disfiguring
- Manual rupture by hitting with large book
  - Not recommended (soft tissue injury)
- Aspiration (ultrasound guided)
  - > 70% complete resolution for cysts alongside flexor tendon sheath (retinacular ganglia)
  - < 50% complete resolution for other ganglia, though they may become smaller and less symptomatic (incomplete resolution)
  - Greater success if ganglion is present for < 1 year
  - Aspiration ± hyaluronidase injection
    - Hyaluronidase degrades hyaluronic acid, which is macromolecular component of ganglion cyst fluid
- Surgical
- Open resection
- Excision of stalk and small portion of joint capsule
  - ≤ 30% may have persistent pain or limitation of movement ± recurrence
  - ~ 5-15% recurrence rate
- Arthroscopic resection: Less scarring
  - Capsular defect, stalk, and cyst debrided from intraarticular approach
  - Similar recurrence rate to open resection

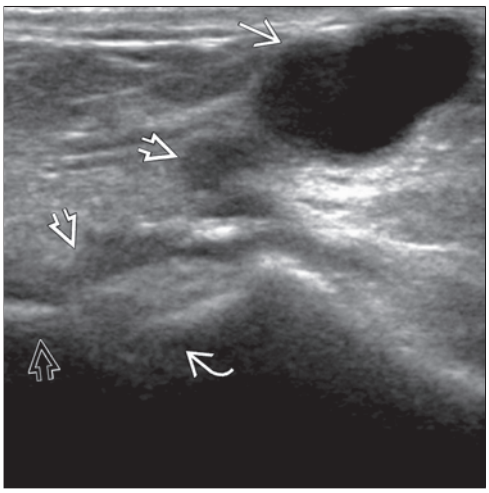
DIAGNOSTIC CHECKLIST

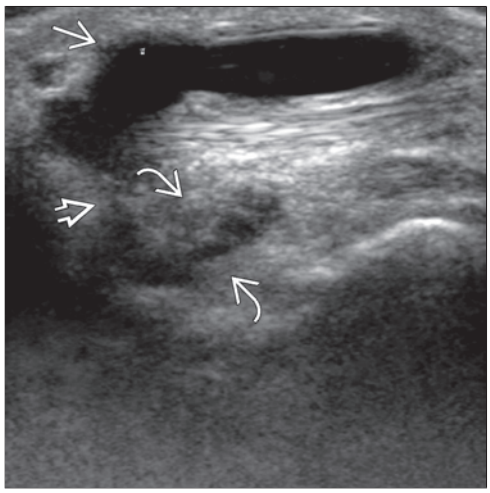
Image Interpretation Pearls
- Locate stalk of ganglion & trace toward joint of origin
- Examine with color Doppler
  - Nerve sheath tumor, giant cell tumor, and vascular anomalies may occasionally simulate cysts

SELECTED REFERENCES

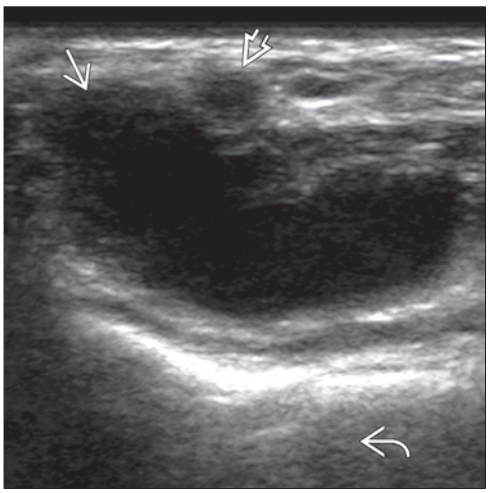
1. Rollins KE et al: Predicting successful outcomes of wrist and finger Ganglia. Hand Surg. 18(1):41-4, 2013

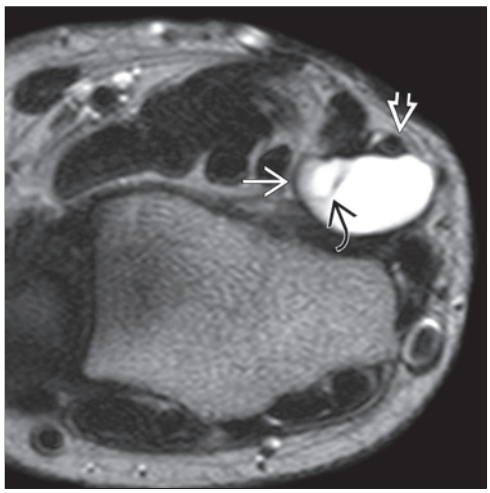
GANGLION CYST



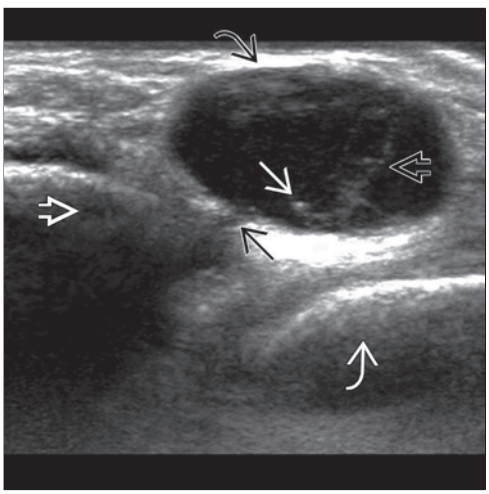


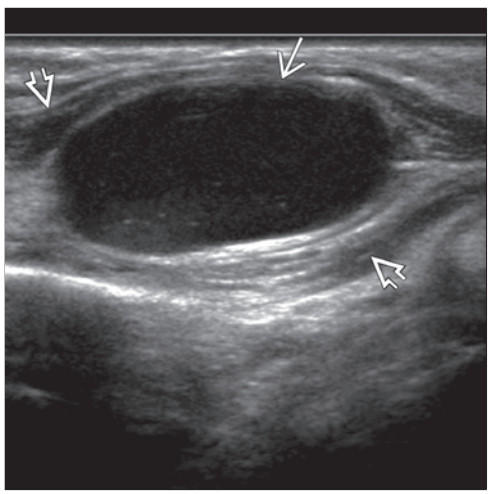
(Left) *Longitudinal ultrasound shows a ganglion arising from a typical location on the radiodorsal aspect of the wrist. The serpiginous stalk of the ganglion extends deeply toward the radiocarpal articulation between the distal radius and the scaphoid bone.* ***(Right)*** *Longitudinal ultrasound shows an elongated ganglion on the radiovolar aspect of the wrist. The stalk of the ganglion extends deeply to lie between the radioscaphocapitate and radiolunotriquetral ligaments.*





(Left) *Transverse ultrasound shows a medium-sized lobulated ganglion on the volar aspect of the distal radius. The ganglion lies deep to the radial artery.* ***(Right)*** *Axial T2WI MR of the same patient shows the ganglion lying deep to the radial artery. There is a thin septum within the ganglion. It is important to identify any large arteries or nerves lying alongside ganglia.*

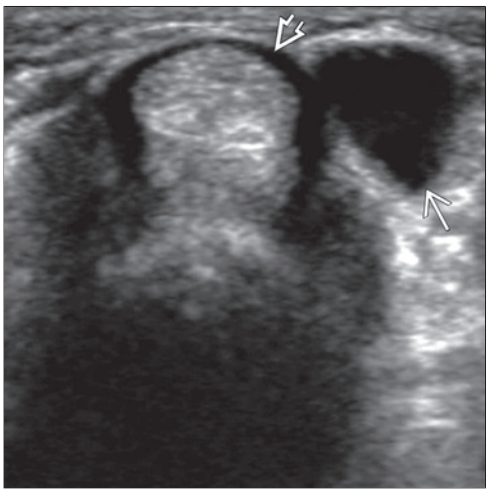


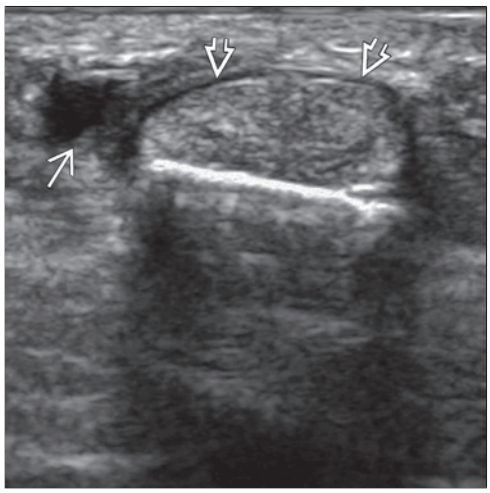


(Left) *Oblique ultrasound shows a small ganglion on the volar aspect of the wrist. The stalk of the ganglion extends into the articulation between the pisiform and the triquetrum. Note a small echogenic focus and a thin septation within the ganglion.* ***(Right)*** *Longitudinal ultrasound shows a unilocular intramuscular ganglion within the thenar muscle. Another view (not shown) showed a stalk extending toward the metacarpophalangeal joint.*

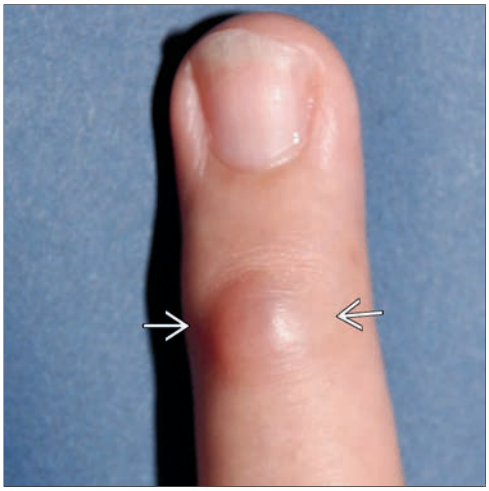
GANGLION CYST

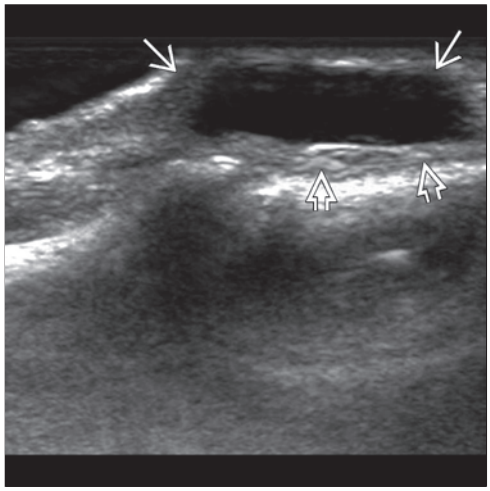
(Left) *Transverse ultrasound shows a small ganglion. The ganglion lies on the radial aspect of the A1 pulley of the middle finger. This type of ganglion is sometimes referred to as a retinacular or pulley ganglion.* ***(Right)*** *Transverse ultrasound shows a small pulley ganglion. The ganglion lies on the ulnar aspect of the A2 pulley of the ring finger. Ganglia are less common around the A2 pulley than around the A1 pulley.*



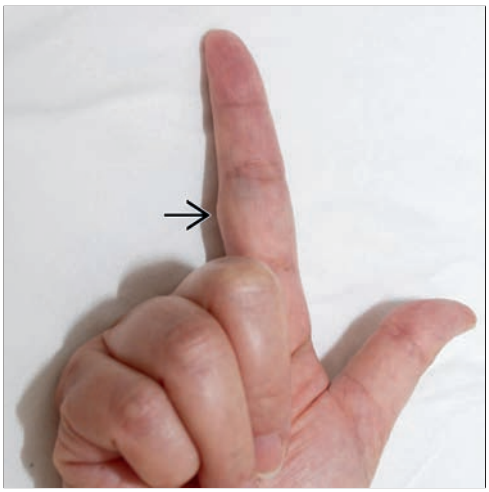


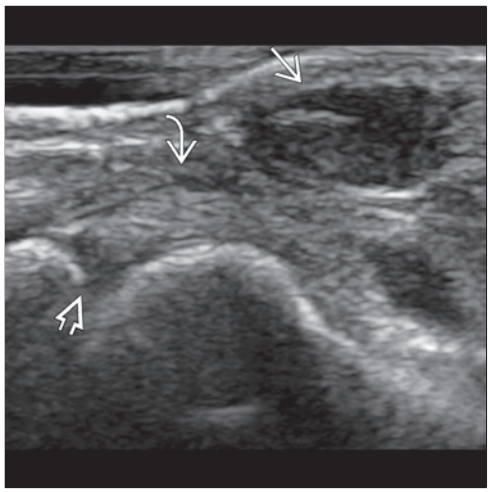
(Left) *Clinical photograph shows swelling consistent with a ganglion on the dorsal aspect of the middle finger. These cysts are covered only by skin and may be translucent.* ***(Right)*** *Longitudinal ultrasound of the same patient shows a subcutaneous unilocular ganglion located dorsal to the extensor tendon of the middle finger. This ganglion most likely arose from the distal interphalangeal joint and is sometimes called a digital mucous cyst.*



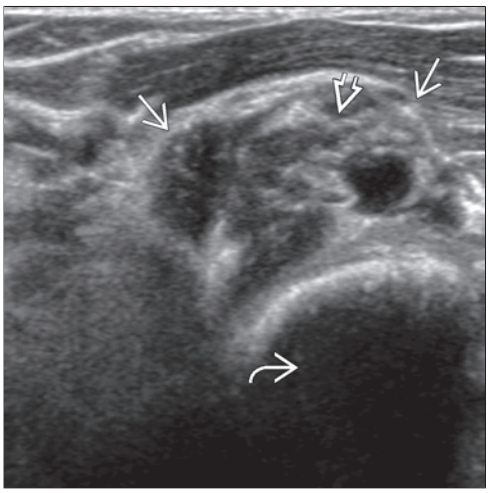


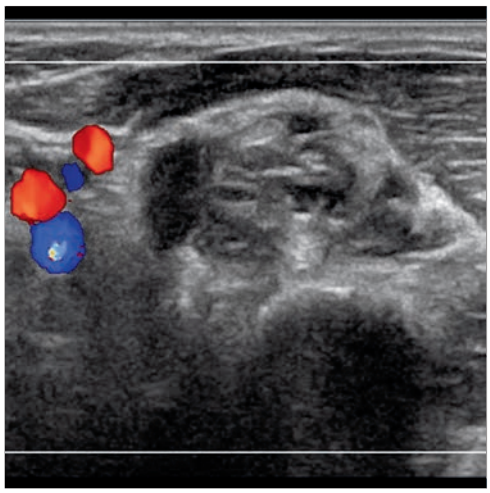
(Left) *Clinical photograph shows a swelling that is suspicious of a ganglion on the ulnovolar aspect of the proximal phalanx close to the proximal interphalangeal joint of the index finger.* ***(Right)*** *Longitudinal ultrasound of the same patient shows an echogenic ganglion just proximal to the proximal interphalangeal joint. No direct communication with the joint is visible, though the thin stalk of the ganglion does point toward the joint.*



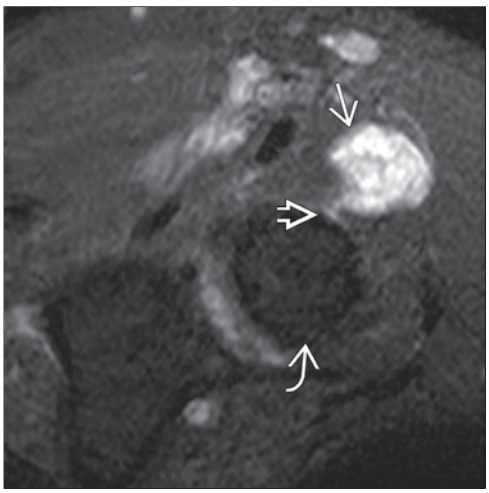


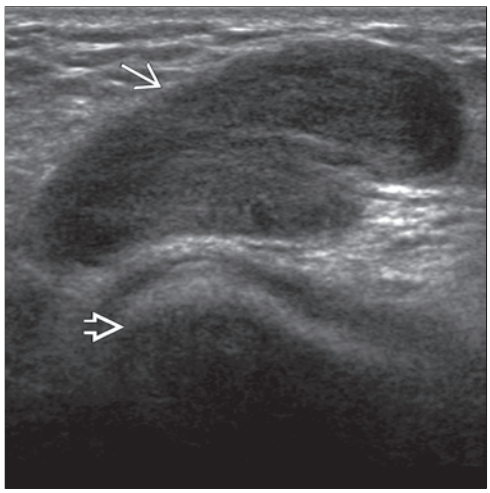
GANGLION CYST



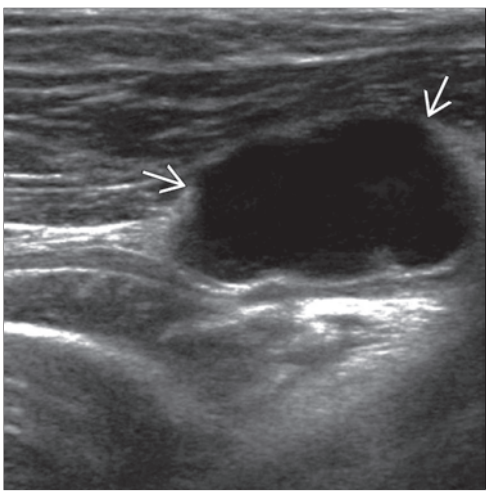


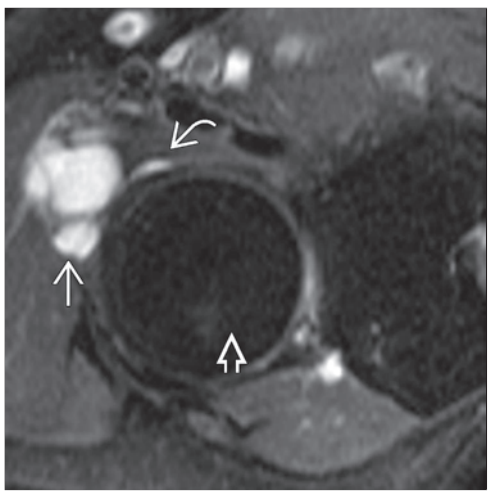
(Left) *Transverse ultrasound shows a complex ganglion with thick septations on the anterior aspect of the elbow just superficial to the radial head. This ganglion can simulate a solid mass.* ***(Right)*** *Transverse color Doppler ultrasound of the same ganglion shows no vascularity within the septa of the ganglion.*





(Left) *Axial T2WI FS MR of the same patient shows the ganglion located anterior to the radial head. A small tract extending from the ganglion toward the elbow joint is visible.* ***(Right)*** *Oblique ultrasound shows a ganglion located posterior to the olecranon process. This should not be confused with an olecranon bursa. A bursa will not point toward the elbow joint.*

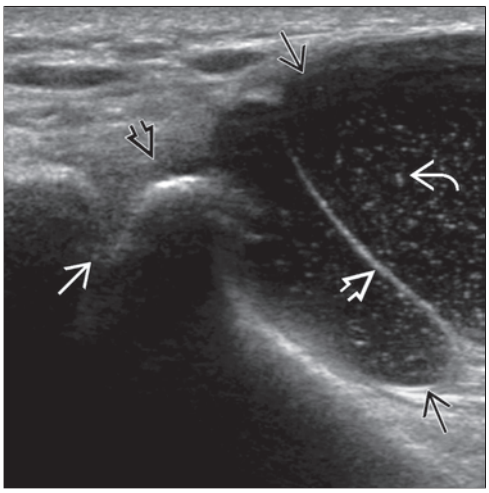


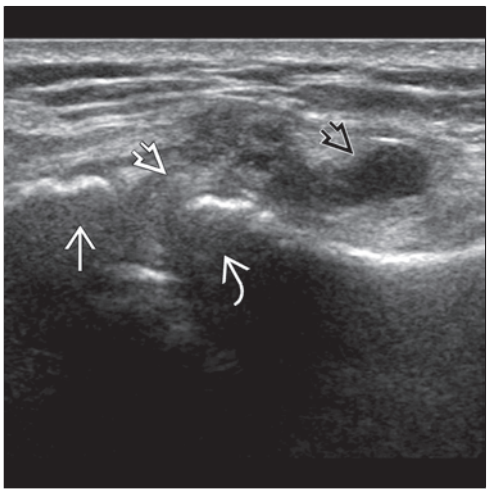


(Left) *Transverse ultrasound shows a lobulated ganglion on the lateral aspect of the elbow joint.* ***(Right)*** *Axial T2WI FS MR of the same ganglion shows that the distal aspect of the ganglion is abutting the radial head with a thin tract extending toward the elbow joint.*

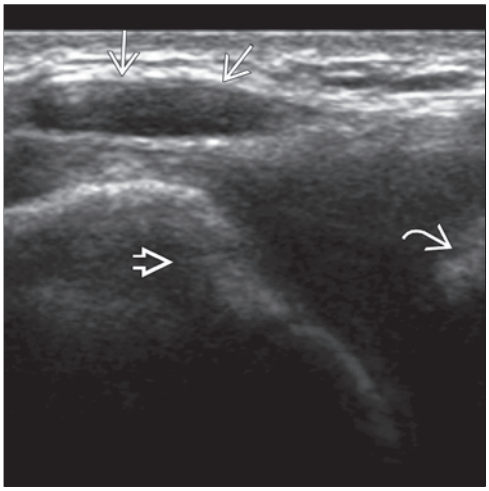
GANGLION CYST

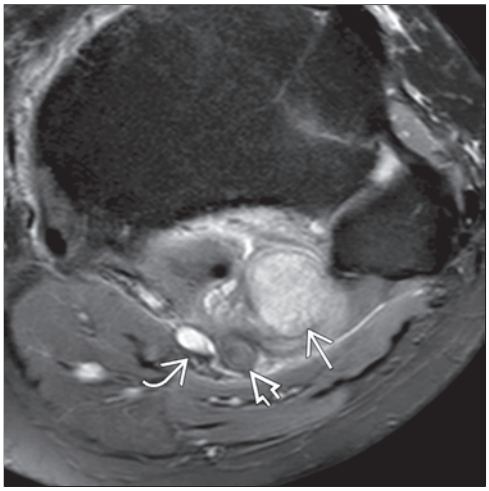
(Left) *Transverse ultrasound shows a large ganglion with septation and internal echogenic foci due to colloid aggregates superficial to the acromioclavicular joint. The stalk of the ganglion extends toward the acromioclavicular joint.* ***(Right)*** *Transverse ultrasound shows a small ganglion anterior to the acromioclavicular articulation. The thick-walled stalk of the ganglion extends toward the acromioclavicular joint. The clavicle and acromion are shown.*



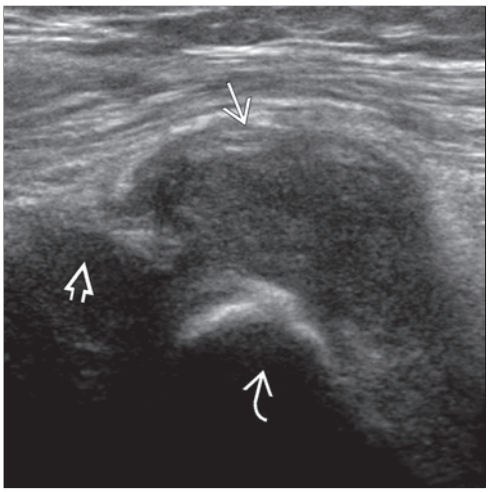


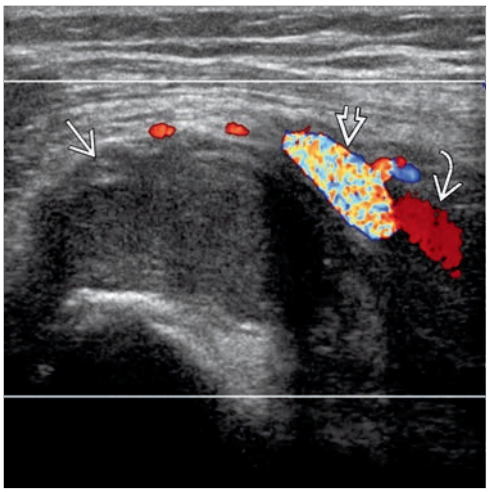
(Left) *Transverse ultrasound shows an elongated ganglion anterior to the sternoclavicular joint. No communication with the joint is evident. The clavicular and sternal ends of the joint are shown* ***(Right)*** *Axial PD FS MR shows a pseudosolid ganglion in the popliteal fossa alongside the popliteal artery and vein .*



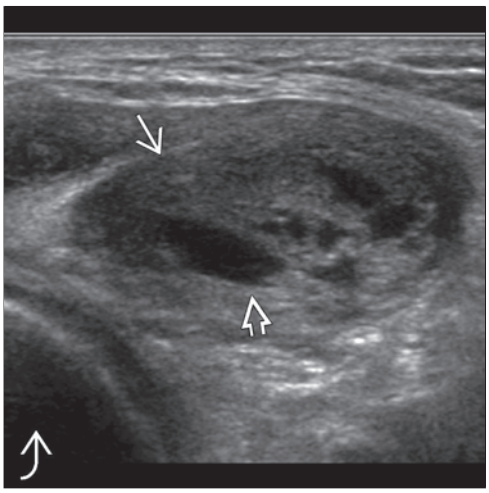


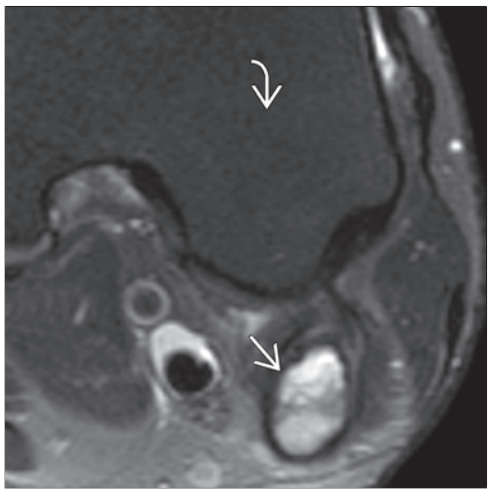
(Left) *Transverse ultrasound of the same mass shows that the ganglion lies just posterior to the proximal tibiofibular joint between the tibia and fibula.* ***(Right)*** *Transverse color Doppler ultrasound of the same patient shows that the ganglion lies alongside the popliteal artery and vein. The pseudosolid appearance of this ganglion is due to internal hemorrhage.*



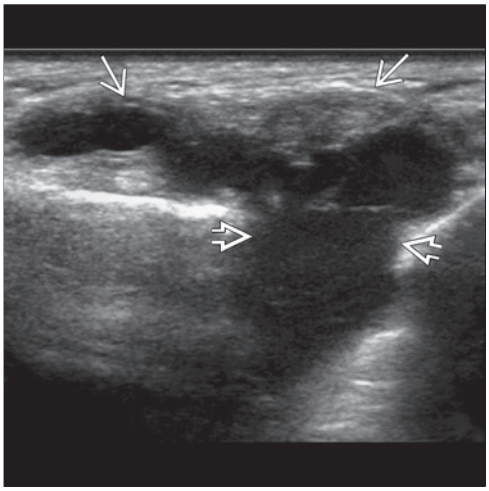


GANGLION CYST



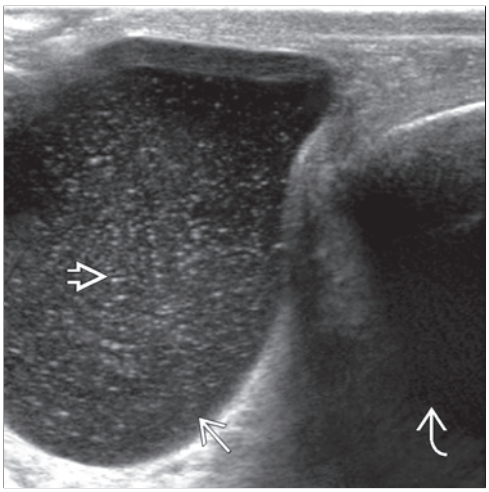


(Left) *Oblique ultrasound shows a ganglion on the posteromedial aspect of the knee joint. The ganglion is thick walled with thick septae. This thickening of the cyst wall is likely to be consequent upon repeated intracystic hemorrhage. The medial femoral condyle is shown.* ***(Right)*** *Axial T2WI FS MR of the same patient shows the ganglion lying posterior to the medial femoral condyle. The ganglion has a hypointense wall suggestive of hemosiderin deposition.*





(Left) *Transverse ultrasound of the knee region shows a ganglion lying anterior to the external opening of the tibial tunnel for an anterior cruciate ligament graft. This tunnel will communicate with the knee joint, allowing for expression of synovial content.* ***(Right)*** *Clinical photograph shows a large cystic swelling on the lateral aspect of the ankle. This swelling occurred 2 days after a relatively minor ankle sprain.*

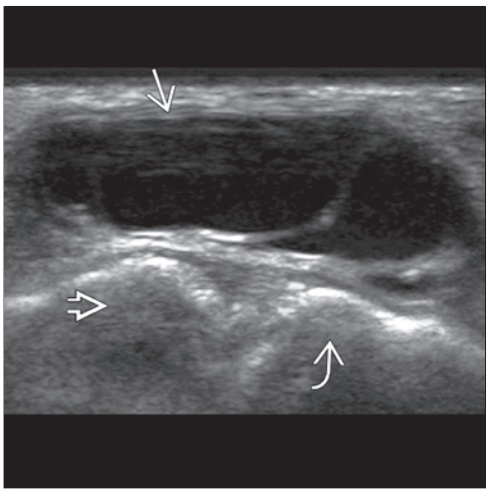


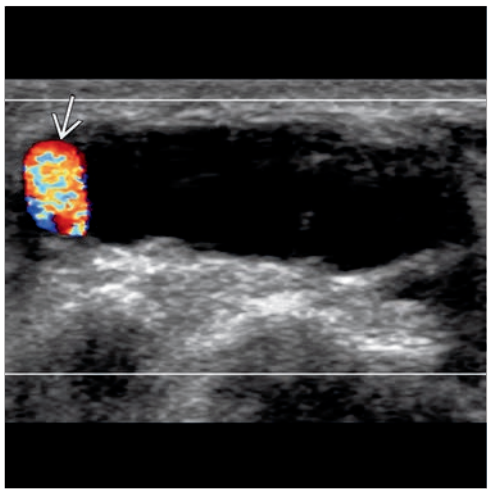


(Left) *Transverse ultrasound of the same patient shows a large, acute, traumatic ganglion lateral to the fibula. The tiny echogenic foci within the ganglion cyst are due to colloid aggregates. They are not a sign of chronicity.* ***(Right)*** *Transverse color Doppler ultrasound of the same patient shows a small tract from the anteromedial aspect of the ganglion extending toward the ankle joint with minimal vascularity in the ganglion wall.*

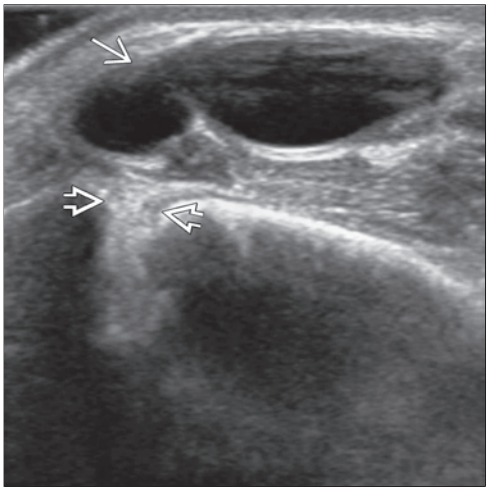
GANGLION CYST

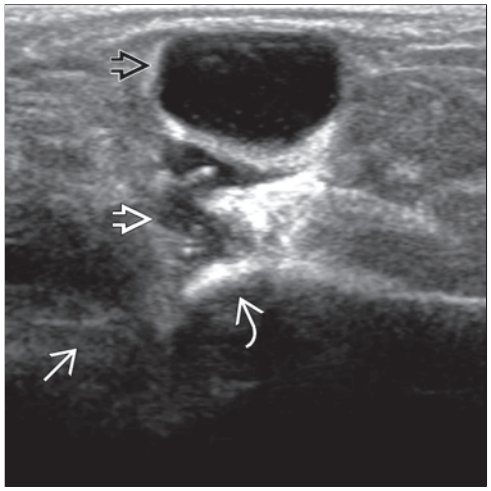
(Left) *Oblique ultrasound shows a ganglion on the dorsal aspect of the foot superficial to the articulation between the intermediate cuneiform and the medial cuneiform. No artery is visible on this image.* ***(Right)*** *Oblique color Doppler ultrasound of the same area shows that the dorsalis pedis artery lies on the side of the ganglion. This artery could potentially be injured during percutaneous aspiration if no color Doppler imaging was performed beforehand.*



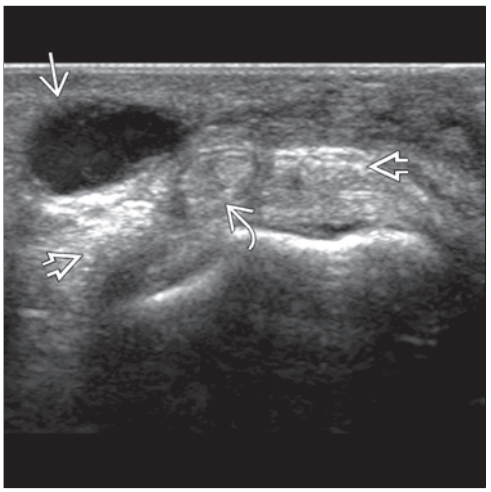


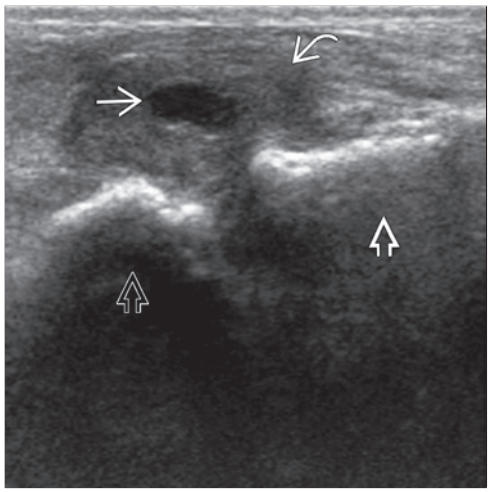
(Left) *Transverse ultrasound shows a lobulated ganglion anterior to the distal tibiofibular articulation. The ganglion lies anterior to the anterior tibiofibular ligament. No direct communication with the joint is evident.* ***(Right)*** *Longitudinal ultrasound shows a small ganglion on the dorsal aspect of the midfoot. The tortuous stalk of the ganglion is arising from the articulation between the cuboid and the 4th metatarsal base.*



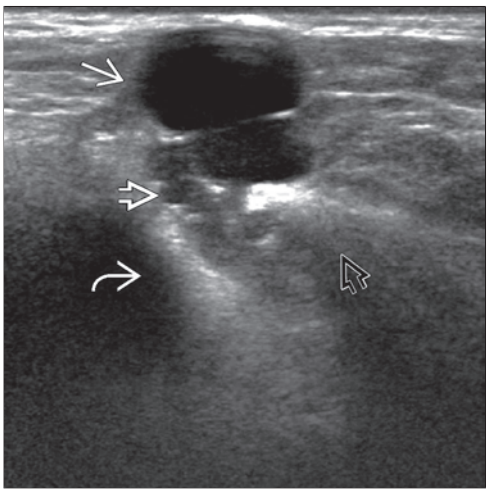


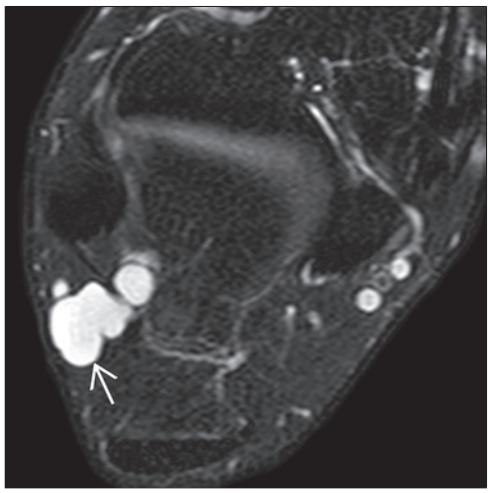
(Left) *Transverse ultrasound shows a ganglion on the plantar aspect of the big toe. The ganglion lies medial to the flexor hallucis longus tendon, which lies between the medial and lateral sesamoid bones.* ***(Right)*** *Oblique ultrasound shows a thick-walled ganglion on the dorsal aspect of the articulation between the navicular and cuneiform bones. This is most likely the result of repeated leakage and recurrent pericyst inflammation. Excessive transducer pressure may efface the fluid component.*





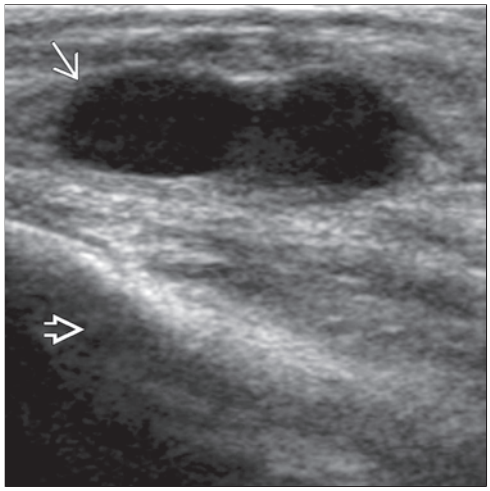
GANGLION CYST





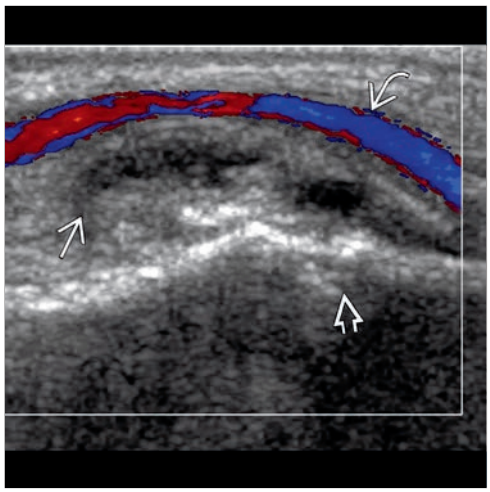
(Left) *Transverse ultrasound shows a small, lobulated ganglion ➔ arising from the posterolateral aspect of the ankle joint. The stalk ➪ of the ganglion extends deep to the articulation between the distal fibula ↝ and the talus ⇨. **(Right)** Axial T2WI FS MR of the same patient shows the lobulated ganglion ➔ on the posterolateral aspect of the ankle. The ganglion stalk is not clearly seen. Occasionally, an ultrasound is superior to MR in this respect.*





(Left) *Clinical photograph shows a small swelling ⇨ on the centrodorsal aspect of the midfoot. **(Right)** Longitudinal ultrasound shows a unilocular uncomplicated ganglion ➔ on the dorsum of the midfoot close to the 2nd ➪ and 3rd metatarsal bases. Dorsal foot ganglia are much more common than plantar foot ganglia. Additional images (not shown) showed the ganglion neck pointing toward the 2nd tarsometatarsal joint.*





(Left) *Clinical photograph shows a small swelling ⇨ on the centrodorsal aspect of the midfoot. **(Right)** Oblique ultrasound shows a thick-walled ganglion ➔ partially collapsed on the dorsal aspect of a narrowed talonavicular articulation ➪. The ganglion lies deep to the dorsalis pedis artery ↝. Most dorsal foot ganglia arise from joints of the medial longitudinal arch in the midfoot region.*

PARAMENISCAL CYST

Key Facts

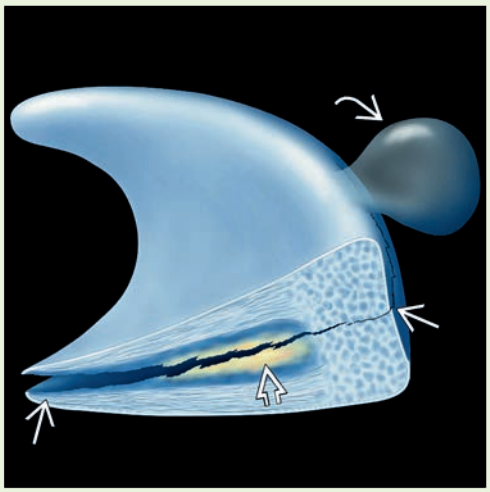
Imaging

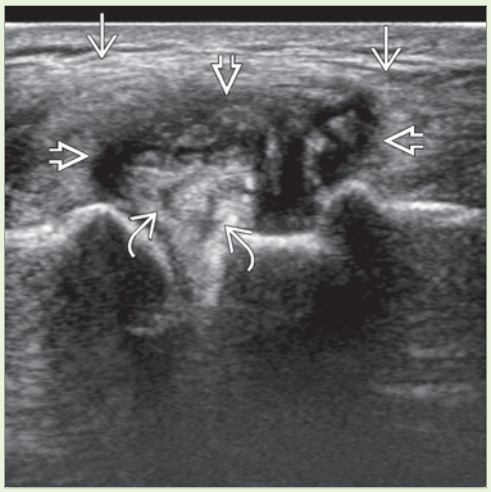
- Cystic mass in continuity with horizontal meniscal tear
  - Medial meniscus parameniscal cyst is slightly more common than lateral meniscus parameniscal cyst
- Meniscal tear forces synovial fluid or mucoid content into parameniscal cyst
- Cyst is usually well defined & filled with anechoic or hypoechoic gelatinous-type fluid
  - Meniscal tear does not always have to be present
  - Especially with anterior horn lateral meniscus
- Cyst may lie in direct continuity with meniscus or connect via serpiginous connecting stalk
- Content of parameniscal cyst is similar to that of paraarticular ganglia & Baker cyst
  - All 3 contain gelatinous material
  - Diagnosis of parameniscal cyst relies on showing continuity between cyst & abnormal meniscus
  - If meniscal communication is not seen, then parameniscal cyst can only be suggested, rather than confirmed, as a diagnosis
- Comment on cyst size, loculation, intra- & extraarticular extent of cyst, associated meniscal tear, recent cyst leakage ± localized inflammation
  - MR to assess for meniscal tear, especially extension to articular surface
- Ultrasound-guided aspiration ± hyaluronidase injection
  - Cyst content may be too viscous to aspirate
  - Temporizing measure only

Diagnostic Checklist

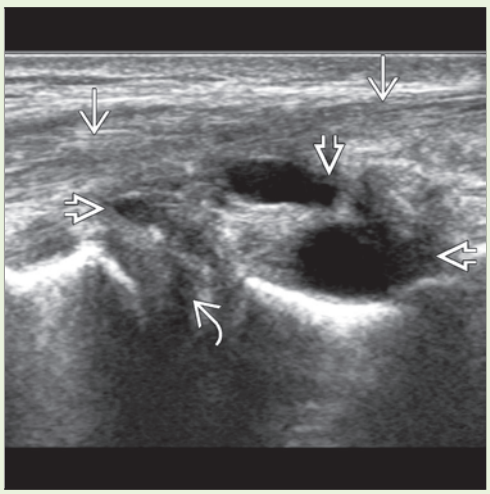
- Not every paraarticular cyst with pedicle extending to knee joint is parameniscal cyst
- Demonstration of meniscal tear extending to articular surface is relevant as this will affect operative approach

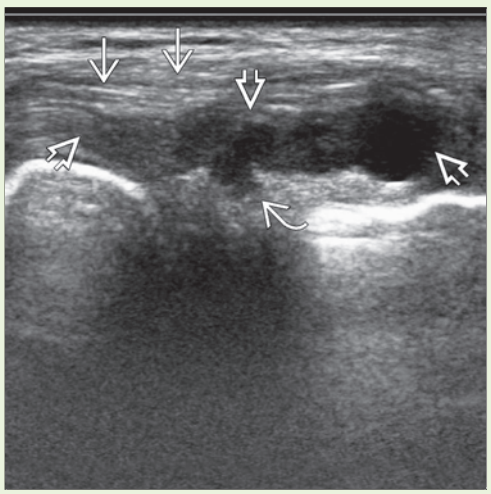
(Left) *Graphic shows horizontal meniscal tear ("fish mouth" tear), with meniscal mucoid degeneration and a small parameniscal cyst arising from the peripheral aspect of the tear.* ***(Right)*** *Longitudinal ultrasound shows a complex tear at the periphery of the extruded medial meniscus. It is associated with a medium-sized parameniscal cyst, which lies deep to the medial collateral ligament.*





(Left) *Longitudinal ultrasound shows a multiseptated parameniscal cyst in the lateral aspect of the knee. It lies deep to the lateral collateral ligament. The cyst extends from a horizontal peripheral tear of the lateral meniscus.* ***(Right)*** *Longitudinal ultrasound shows a parameniscal cyst deep to the medial collateral ligament. The cyst connects to a horizontal peripheral tear of the medial meniscus.*





PARAMENISCAL CYST

TERMINOLOGY

Synonyms
- Meniscal cyst

Definitions
- Cyst extending from meniscal tear
  - Usually a horizontal tear

IMAGING

General Features
- Best diagnostic clue
  - Cystic mass in continuity with horizontal meniscal tear
- Location
  - Can arise from any part of meniscus
    - Medial meniscus (~ 60%), lateral meniscus (~ 40%)
  - Most common locations
    - Posterior aspect of body & horn medial meniscus (posterior to medial collateral ligament)
    - Anterior aspect of body & anterior horn lateral meniscus (anterior to lateral collateral ligament)
- Size
  - Tiny (few mm) to large extraarticular cyst (> 10 cm)
- Morphology
  - Extension from parameniscal area subject to capsuloligamentous anatomy on medial & lateral aspects of knee
  - Cysts from medial meniscus often extend either
    - Inferiorly deep to semimembranous & pes anserinus tendons
    - Anteriorly superficial to medial collateral ligament
  - Cysts from lateral meniscus often extend deep to iliotibial tract or lateral collateral ligament
  - Medial parameniscal cysts especially can extend quite a distance from meniscal tear
    - Consider parameniscal cyst for any medially located cyst
  - Lateral cysts tend to remain closer to knee capsule

MR Findings
- T1WI
  - Hypointense cyst mass
  - If proteinaceous, cyst may be iso- or hyperintense
  - Hyperintense mucoid degeneration of meniscus
- T2WI
  - Rounded, hyperintense mass
    - Lobulation & septation
  - Tear = linear hyperintense meniscal signal extending to articular surface
    - Peripheral meniscal tear may not visibly connect with meniscal articular surface (noncommunicating tear)

Ultrasonographic Findings
- Horizontal meniscal tear + parameniscal cyst ± extraarticular component with communicating stalk
  - Meniscal tear does not always have to be present, especially from anterior horn of lateral meniscus
- Meniscus is seen as diffusely echogenic, sharply defined structure within medial & lateral femoral-tibial compartments of knee
  - Medial meniscus is easier to see on ultrasound
    - Only peripheral part of menisci can be seen on ultrasound
  - Body of menisci is best seen with limited views of other areas
- Meniscal tear = linear or wedge-shaped hypoechogenicity within meniscus extending to meniscal periphery
- Parameniscal cyst
  - Usually well defined & filled with anechoic or hypoechoic gelatinous-type fluid or rarely can have heterogeneous hyperechoic appearance
  - ± multiloculation, ± septation
  - ± "comet tail" artifacts due to colloid aggregates
  - ± echogenic mass/debris (due to proteinaceous content or previous hemorrhage)
  - Cyst is usually thin walled
  - Edema, swelling, & hyperemia around cyst usually indicate recent leakage, which leads to localized inflammation
- Cyst may lie in direct continuity with meniscus or connect via connecting stalk (pedicle)
  - Small intrameniscal cyst may be visible
- Communicating stalk is usually serpiginous & narrow
  - Cyst may be located at some length from meniscal tear
- Cyst & contents of parameniscal cyst are similar to paraarticular ganglia & Baker cyst: All 3 contain gelatinous material
  - Main differences
    - Stalk in parameniscal cyst → meniscal tear
    - Stalk in paraarticular ganglion → joint
    - Stalk in Baker cyst → between semimembranous tendon & medial gastrocnemius muscle → joint
- If meniscal communication is not seen, then parameniscal cyst can only be suggested as diagnosis
  - Sometimes difficult to distinguish parameniscal cyst & paraarticular ganglion

Imaging Recommendations
- Best imaging tool
  - Ultrasound: First line of investigation
    - Very accurate at detecting cystic nature of paraarticular mass
    - Will show meniscal origin in majority of parameniscal cysts
  - MR: Helpful to fully assess meniscal integrity
    - Best to show meniscal tear, articular surface extension of tear, & degree of meniscal mucoid degeneration
- Examine with knee extended
- Determine if cyst is in continuity with meniscus
  - Determine whether meniscal tear is at contact point with cyst
- If extraarticular cyst, locate stalk of cyst
  - Trace stalk of cyst to knee joint
  - Determine if stalk originates from meniscal tear
- Note relationship of cyst to adjacent structures
  - Medially
    - Medial collateral ligament
    - Pes anserinus (sartorius, gracilis, semitendinous) tendons
  - Laterally
    - Iliotibial band
    - Lateral collateral ligament

PARAMENISCAL CYST

- Examine with varying degrees of flexion to accentuate visualization of meniscal tear ± stalk (optional)
- Examine anterior horn of menisci with knee flexed

DIFFERENTIAL DIAGNOSIS

Paraarticular Ganglion Cyst
- Can extend from intraarticular to extraarticular compartment
- Does not originate from meniscal tear

Bursitis
- Medial parameniscal cyst mimicked by
  - Semimembranosus bursitis, pes anserinus bursitis, or medial collateral ligament bursitis
- Lateral parameniscal cyst mimicked by
  - Deep infrapatellar bursa (anteriorly located)

Baker Cyst
- Distension of semimembranous-gastrocnemius bursa
  - Popliteal cyst with "talk-bubble" configuration
  - Stalk arises from interspace between semimembranous tendon & medial belly gastrocnemius
  - No connection with meniscus

PATHOLOGY

General Features
- Etiology
  - All have underlying meniscal abnormality
    - > 90% have meniscal tear; remainder have meniscal mucoid degeneration
    - Mainly horizontal tear
  - Forcing of synovial joint fluid through horizontal meniscal tear into cyst
    - Compression/decompression of horizontal tear with knee flexion/extension explains association with this type of tear
    - Ball-valve mechanism
  - Only 2/3 of tears associated with parameniscal cyst extend to meniscal articular surface
  - Possible explanations
    - Articular extension is minute & too small to see or may have healed
    - Cyst content is generated solely from meniscal mucoid degeneration & not synovial fluid
  - Many also arise from complex meniscal tear or radial split tear with horizontal component
  - Anterior horn of lateral meniscus parameniscal cyst typically not associated with meniscal tear
    - Cyst extends to Hoffa fat pad or into anterior meniscal root
  - About 10% of parameniscal cysts do not have associated meniscal tear
    - These parameniscal cysts may arise from tear of meniscocapsular ligaments
      - In this case, the term parameniscal cyst is arguable
  - Horizontal tear & parameniscal cyst is associated with discoid meniscus

Gross Pathologic & Surgical Features
- Cyst filled with mucinous-type fluid
  - In continuity with horizontal cleavage meniscal tear or flap (oblique) tear with predominately horizontal component

CLINICAL ISSUES

Presentation
- Most common signs/symptoms
  - Palpable mass ± pain/discomfort near joint line ± limitation of movement
  - Size varies with knee position
    - Palpable lateral cyst at 15-30° of flexion, which disappears at full extension & flexion (Pisani sign)
  - Consistency varies from fluctuant to firm or hard

Demographics
- Age
  - Peak: 20-40 years; mean: 41 years
- Gender
  - M > F
- Epidemiology
  - Relatively common: 2-4% of all knee MR exams

Treatment
- Arthroscopic or open resection of cyst & repair of tear
  - Tear must be closed to prevent reemergence of cyst
- Ultrasound-guided aspiration of cyst
  - ± intracystic percutaneous steroid injection
  - Cyst tends to recur, but good temporary measure
  - Not possible to predict viscosity of cyst contents on ultrasound
  - Viscosity determined during attempted aspiration

DIAGNOSTIC CHECKLIST

Consider
- Not every paraarticular cyst with stalk extending to knee joint is parameniscal cyst
  - Intraarticular ganglion cyst with paraarticular extension can look very similar
- Demonstration of meniscal tear extending to articular surface is relevant as this will affect operative approach
  - Arthroscopic if communicating meniscal tear present
  - Open if noncommunicating meniscal tear present

Image Interpretation Pearls
- Cyst alongside meniscus in continuity with meniscal tear = parameniscal cyst
  - Meniscal tear usually has horizontal component

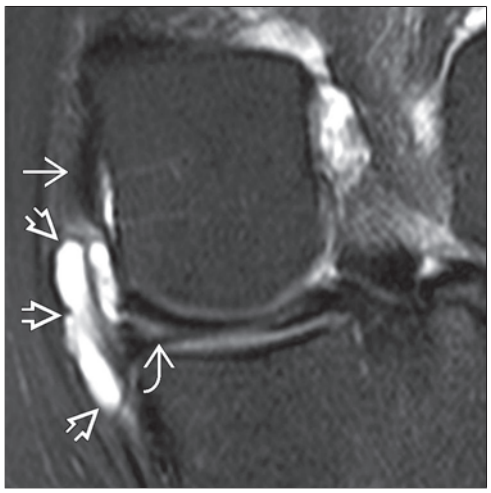
Reporting Tips
- Comment on cyst size, loculation, extent of cyst, associated meniscal tear, recent cyst leakage, or localized inflammation
- MR to assess for meniscal tear, especially extension to articular surface

SELECTED REFERENCES

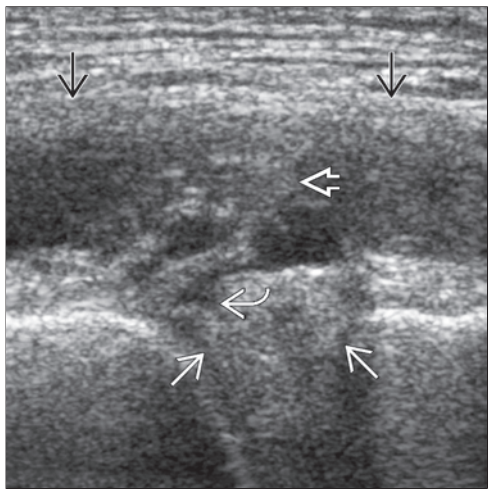
1. De Smet AA et al: Association of parameniscal cysts with underlying meniscal tears as identified on MRI and arthroscopy. AJR Am J Roentgenol. 196(2):W180-6, 2011
2. McCarthy CL et al: The MRI appearance of cystic lesions around the knee. Skeletal Radiol. 33(4):187-209, 2004

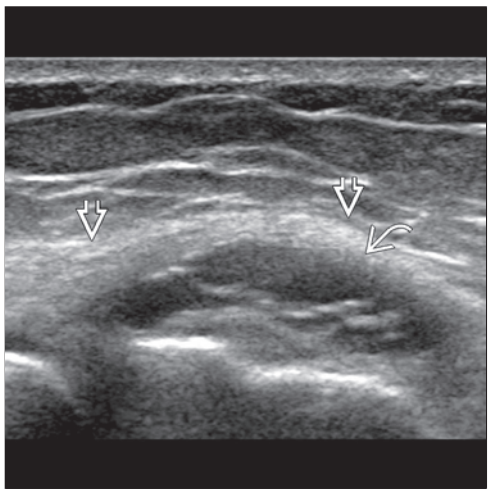
PARAMENISCAL CYST



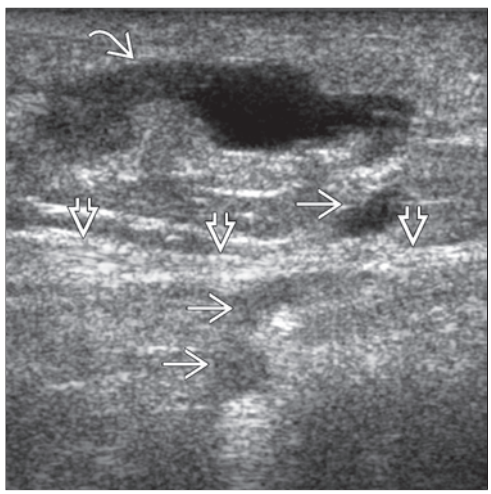


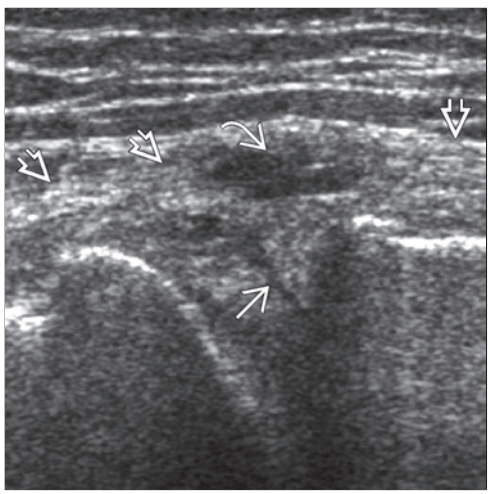
(Left) *Clinical photo shows moderate swelling on the medial aspect of the knee around the medial joint line due to a parameniscal cyst.* ***(Right)*** *Coronal T2WI FS MR of the same patient shows a multiseptated parameniscal cyst extending through the medial collateral ligament. The cyst originates from a horizontal tear in the posterior horn of the medial meniscus.*





(Left) *Lateral ultrasound shows a parameniscal cyst with mixed echogenic content displacing the medial collateral ligament. The cyst is continuous with a tear in the peripheral aspect of the medial meniscus.* ***(Right)*** *Longitudinal ultrasound shows a large parameniscal cyst deep to the medial collateral ligament. The meniscal tear is not evident on ultrasound but was present on MR (not shown).*





(Left) *Transverse ultrasound shows a mixed echogenic parameniscal cyst on the lateral side of the knee. The stalk extends through the lateral collateral ligament toward the lateral meniscus.* ***(Right)*** *Lateral ultrasound shows a tear in the peripheral aspect of the medial meniscus with a parameniscal cyst extending into the medial collateral ligament.*

SYNOVIAL TUMOR

Key Facts

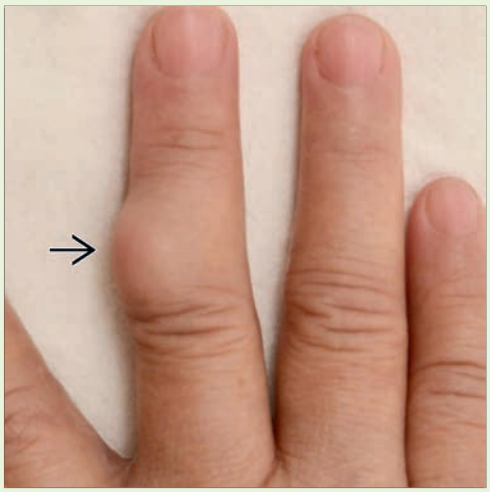
Terminology

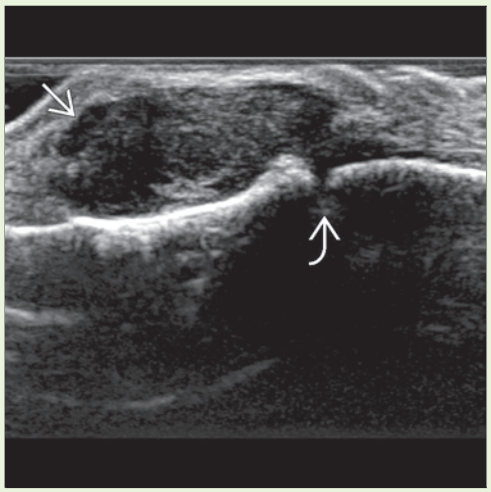
- Pigmented villonodular synovitis (PVNS), focal nodular synovitis (FNS), giant cell tumor of tendon sheath (GCTTS)
  - Other less common synovial tumors: Lipoma arborescens, synovial hemangioma, synovial lipoma, synovial fibroma, synovial chondrosarcoma, synovial infiltration (e.g., lymphoma)

Imaging

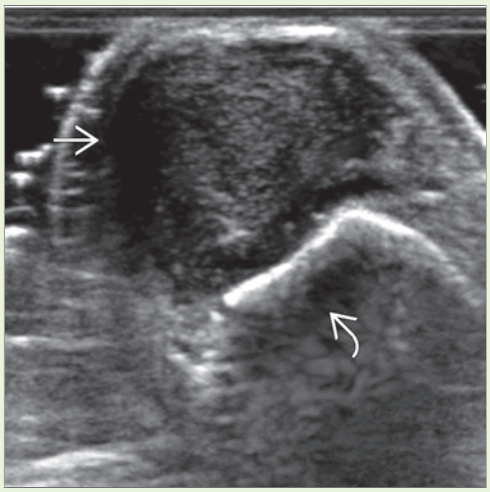
- PVNS: Tumor-like hypoechoic hypervascular synovium
  - 90% occur in synovial-lined joints, tendon sheaths, & bursae; multicentric occurrence is rare
  - 10% of extraarticular PVNS tumors may not have demonstrable connection to joint, tendon sheath, or bursa
  - Knee (60%) > hip > ankle > small joints of hand & foot > shoulder & elbow
- PVNS (diffuse intraarticular)
  - Lobular thickening of hypoechoic synovium
  - Variable synovial hyperemia
  - Hemosiderin not visible on ultrasound
  - ± intraarticular bony scalloping ± small effusion
- FNS (focal intraarticular)
  - Well-defined hypoechoic intraarticular nodule
  - ± mild hyperemia ± effusion
- GCTTS: Eccentric nodular mass along tendon sheath ± hyperemia
  - Hand & wrist (80%) > foot & ankle (20%)
- Synovial osteochondromatosis: Thickened synovium with discrete echogenic foci ± hyperemia
  - No acoustic shadowing if pure cartilage nodules
  - Knee > elbow > hip & shoulder; polyarticular (5%)
- Most synovial tumors: Confirm with ultrasound-guided core biopsy as ultrasound appearances are often not specific enough to make definitive diagnosis

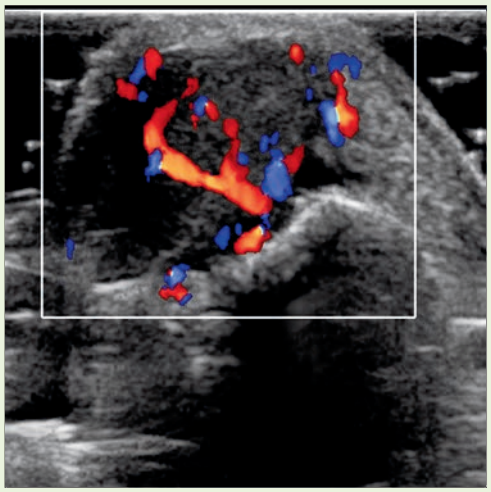
(Left) *Clinical photograph shows a painful middle finger mass* → *that had been slowly growing for 2 years.* ***(Right)*** *Longitudinal ultrasound of the same patient shows a medium-sized mass* ➡ *on the dorsoradial aspect of the middle finger at the level of and distal to the proximal interphalangeal joint* ➡. *The appearances are consistent with pigmented villonodular synovitis (PVNS) arising from the proximal interphalangeal joint.*





(Left) *Transverse ultrasound in the same patient shows the typical hypoechoic appearance of PVNS* ➡ *with mild scalloping of the underlying middle phalanx* ➡. ***(Right)*** *Transverse color Doppler ultrasound of the same patient shows moderate tumoral hyperemia. This level of hyperemia is quite typical for PVNS, though some PVNS tumors may be relatively hypovascular.*





SYNOVIAL TUMOR

TERMINOLOGY

Abbreviations
- Pigmented villonodular synovitis (PVNS)
- Giant cell tumor of tendon sheath (GCTTS)
- Focal nodular synovitis (FNS)

Synonyms
- GCTTS: Tenosynovial giant cell tumor

Definitions
- PVNS (diffuse or focal) & GCTTS: Recently recategorized as fibrohistiocytic tumors
- FNS: Localized variant, though separate tumor entity from PVNS
- Synovial osteochondromatosis: Synovial metaplasia characterized by cartilaginous loose bodies that later ossify
- Other less common synovial tumors
  - Lipoma arborescens, synovial hemangioma, synovial lipoma, synovial fibroma, synovial chondrosarcoma, synovial infiltration (e.g., lymphoma)
    - Synovial sarcoma is misnomer since not derived from true synovial cells

IMAGING

General Features
- Best diagnostic clue
  - PVNS: Tumor-like hypoechoic hypervascular synovium
    - 90% occur in synovial-lined joints, tendon sheaths, & bursae; multicentric occurrence is rare
      - 10% of extraarticular PVNS tumors shows no demonstrable connection to joint, tendon sheath, or bursa
      - Connection either tenuous or tumor arose de novo in other tissues
  - GCTTS: Eccentric nodular mass along tendon sheath ± hyperemia
  - Synovial osteochondromatosis: Thickened synovium with small discrete echogenic foci ± hyperemia
- Location
  - PVNS & FNS: Knee (60%) > hip > ankle > small joints of hand & foot > shoulder & elbow
  - GCTTS: Hand & wrist > foot & ankle
    - Logically, GCTTS should occur only where there is synovial-lined tendon sheath
  - Synovial osteochondromatosis: Knee > elbow > hip & shoulder; polyarticular (5%)
- Size
  - PVNS, FNS, & GCTTS: Thickened synovial mass ranging from a few cm to 20 cm
  - Synovial osteochondromatosis: Nodules ranging from a few mm to ~ 20 mm

Radiographic Findings
- Radiography
  - PVNS
    - Dense soft tissue swelling
      - ± intraarticular erosions with sclerotic margins, especially in hip (tight capsule)
    - Preservation of joint space till late
    - No juxtaarticular osteopenia
  - Synovial (osteo)chondromatosis
    - Multiple small ossified bodies within joint
    - Cartilage nodules not ossified in 20%
      - ± intraarticular erosions, especially in hip
    - Preservation of joint space till late
    - No juxtaarticular osteopenia

MR Findings
- T1WI
  - PVNS
    - Isointense to hypointense mass or masses
- T2WI
  - PVNS
    - Hypointense to isointense synovial mass secondary to paramagnetic effect of hemosiderin
    - ± intermediate signal erosions with hypointense margins
- T2* GRE
  - PVNS
    - Foci of hypointensity due to hemosiderin deposits
    - Hemosiderin is present in 85% of PVNS cases, i.e., lack of hemosiderin does not exclude diagnosis
    - FNS contains less hemosiderin than diffuse PVNS

Ultrasonographic Findings
- PVNS (diffuse intraarticular)
  - Lobular thickening of hypoechoic synovium
  - Variable synovial hyperemia
  - Hemosiderin not visible on ultrasound
  - ± intracapsular bony erosion ± effusion
- FNS (focal intraarticular)
  - Well-defined hypoechoic intraarticular nodule
- GCTTS
  - Eccentric hypoechoic mass along tendon sheath
  - ± mild hyperemia
  - Otherwise normal tendon & tendon sheath
- Synovial osteochondromatosis
  - Mild to moderate synovial thickening with small effusion
  - Multiple small echogenic nodules
  - Nonossified cartilaginous nodules may be difficult to see on ultrasound
    - Hypoechoic similar to joint fluid
  - ± mild hyperemia
- Nearly all synovial tumors
  - Use ultrasound-guided core biopsy for histological confirmation
  - Ultrasound appearances are usually not specific enough to make definitive diagnosis

Imaging Recommendations
- Best imaging tool
  - Ultrasound for initial assessment
    - Most synovial tumors are readily seen by ultrasound
    - If synovium clearly seen in full and is normal, then no synovial tumor
    - Allows ultrasound-guided synovial biopsy for definitive histological confirmation
  - MR for defining extent
    - Ultrasound can suggest diagnosis of most synovial tumors, though MR is more specific & better defines extent
  - Radiography for synovial osteochondromatosis
- Protocol advice

SYNOVIAL TUMOR

- Look carefully for any articular or tendon sheath involvement of extraarticular masses
- Look for bone erosion or scalloping
- Always access with color Doppler imaging
  - Use minimal transducer pressure to avoid vascular blanching

DIFFERENTIAL DIAGNOSIS

Hemophilic Arthropathy
- Familial (X-linked)
- ± polyarticular ± hemarthrosis

Synovitis
- Systemic inflammatory disorder
- ± polyarticular + RA factor positive

Synovial Hemangioma
- Vascular anomaly involving synovium
- Phleboliths & venous lakes ± hemarthrosis

PATHOLOGY

General Features
- PVNS
  - Synovial proliferative disorder
    - Diffuse or nodular (focal) forms
      - Nodular PVNS is known as FNS
      - Although histologically almost identical, FNS seems to be separate entity from diffuse PVNS
- FNS
  - Localized to 1 area of synovium
  - Does not have frond-like projections
  - Has less hemosiderin deposition
  - Tends to become more pedunculated with growth
- Synovial osteochondromatosis
  - Synovial metaplasia

Gross Pathologic & Surgical Features
- PVNS (diffuse or focal)
  - Yellow-brown cut surface (fat & hemosiderin)
  - ± joint filled with nonclotted blood
- GCTTS
  - Rubbery, encapsulated, multinodular mass
  - Yellow-brown cut surface
- Synovial (osteo)chondromatosis
  - Synovial thickening
  - Multiple small calcified or ossified bodies, both free & attached to synovium

Microscopic Features
- PVNS & GCTTS
  - Synovial mass with fibrohistiocytic cells, foamy histiocytes, & giant cells with hemosiderin
- Synovial osteochondromatosis
  - Initial active phase of synovial proliferation without loose bodies
    - Progresses to late inactive phase with quiescent synovial disease & loose bodies
  - Multiple nodules of hyaline cartilage formed within subsynovial connective tissue
  - Later ossify (endochondral ossification)
    - Nodules may contain cartilage, cartilage & bone, or mature bone with fatty marrow

CLINICAL ISSUES

Presentation
- Most common signs/symptoms
  - Joint swelling
- Other signs/symptoms
  - Pain
  - Limitation of movement

Demographics
- Age
  - Typically 30-50 years
- Gender
  - PVNS: M:F = 2:1
  - GCTTS: M:F = 1:1
  - Synovial osteochondromatosis: M:F = 2:1

Natural History & Prognosis
- PVNS: → progressive arthropathy
- FNS & GCTTS: Good response to excision
- Synovial osteochondromatosis: Active → inactive phase

Treatment
- PVNS (diffuse)
  - Synovectomy
  - Recurrence
    - 20% after complete (open) synovectomy
    - 50% after incomplete (arthroscopic) synovectomy
  - Intraarticular yttrium-90 radiation synovectomy
- GCTTS & FNS
  - Limited synovectomy
- Synovial osteochondromatosis
  - Synovectomy
  - Recurrence in 15%

DIAGNOSTIC CHECKLIST

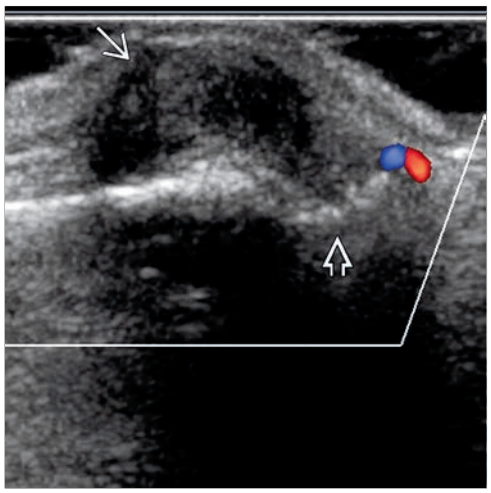
Consider
- Diffuse PVNS & FNS probably represent separate entities

Image Interpretation Pearls
- PVNS: Diffuse hypoechoic synovial mass with variable hyperemia
  - T2* GRE identifies hemosiderin (hypointense)
    - Not imperative to see hemosiderin on gradient-echo MR imaging to make diagnosis of PVNS
- FNS: Localized hypoechoic synovial mass with variable hyperemia
  - Contains less hemosiderin than PVNS
- GCTTS (extraarticular)
  - Eccentric (rather than concentric) tendon sheath mass
- Synovial osteochondromatosis: Calcified bodies not invariably visible in early stages
- Ultrasound-guided biopsy will confirm diagnosis of most synovial tumors

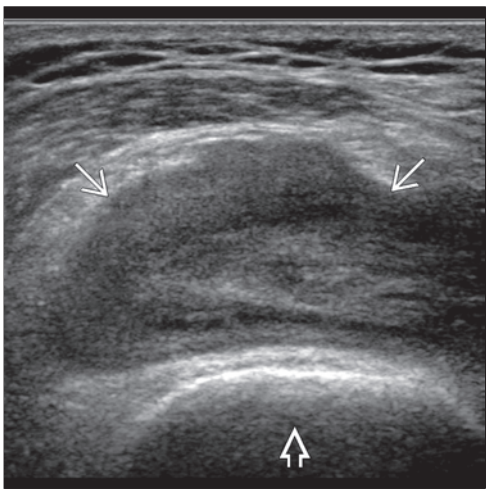
SELECTED REFERENCES

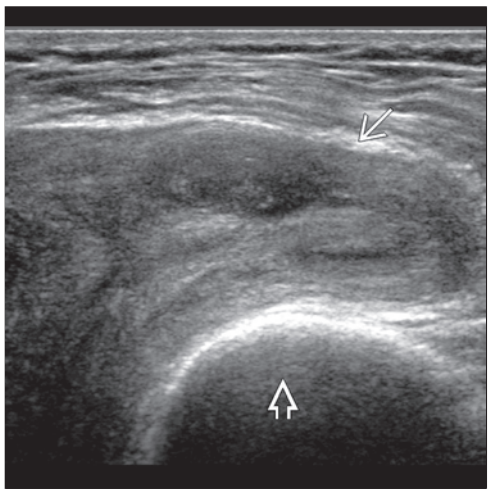
1. Garner HW et al: Benign synovial tumors and proliferative processes. Semin Musculoskelet Radiol. 17(2):177-8, 2013



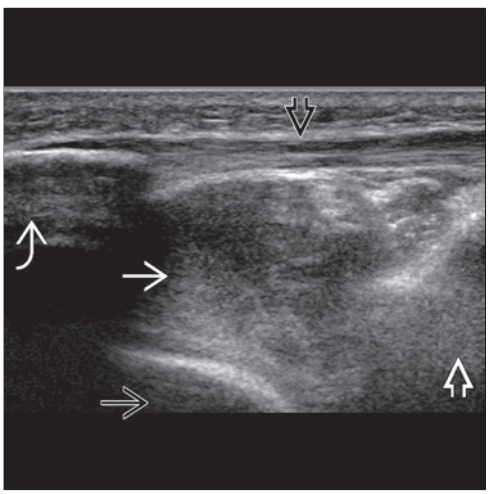


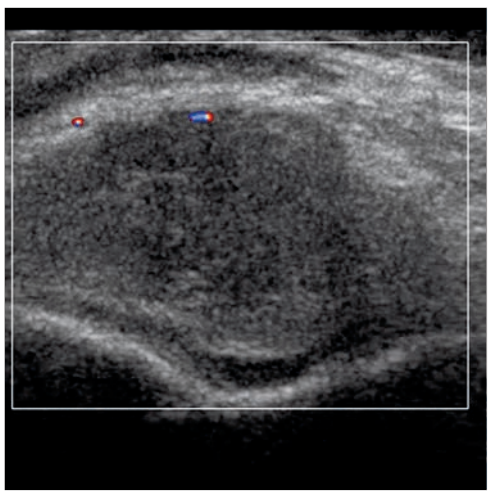
(Left) *Clinical photograph shows a thumb mass that had been present for 12 months.* ***(Right)*** *Longitudinal color Doppler ultrasound of the same patient shows a medium-sized hypoechoic solid mass that was in contact with the dorsal capsule of the interphalangeal joint (not shown). No demonstrable tumor hyperemia is present. Overall appearances favor PVNS, confirmed by histology. The apparent bone scalloping is spurious due to probe obliquity.*





(Left) *Transverse ultrasound of the lateral patellofemoral recess shows severe hypoechoic synovial proliferation. The femur is normal. Diffuse knee swelling had been present for 1 year prior to this ultrasound.* ***(Right)*** *Transverse ultrasound of the medial patellofemoral recess in the same patient shows similar severe hypoechoic synovial proliferation. The femur is normal.*

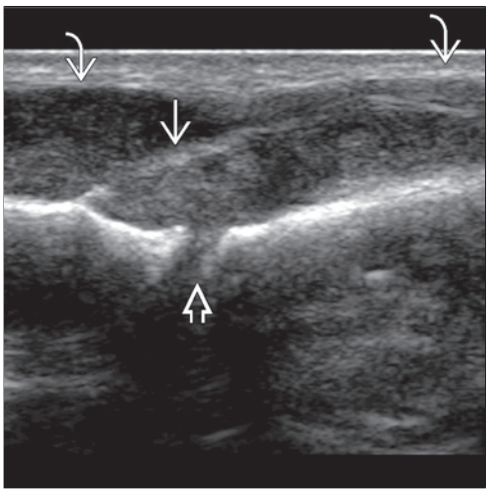


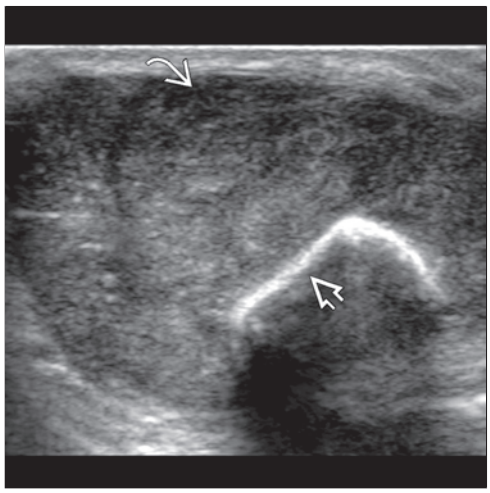


(Left) *Longitudinal ultrasound of the same patient as previous image shows severe synovial proliferation bulging into the infrapatellar fat pad. The patella, patellar tendon, distal femur, & proximal tibia are normal.* ***(Right)*** *Transverse color Doppler ultrasound of the same patient shows minimal hyperemia. This does not exclude a diagnosis of intraarticular PVNS, which was confirmed by ultrasound-guided biopsy (not shown) for histology.*

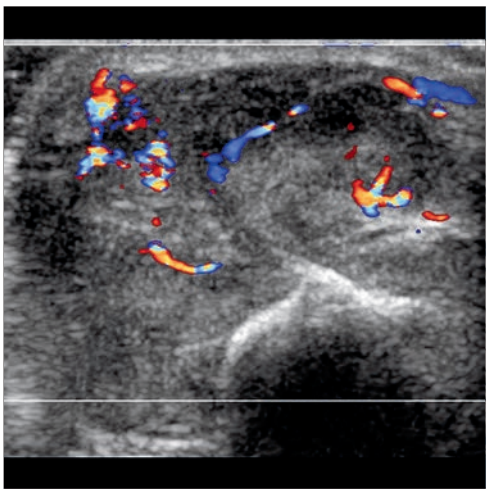
SYNOVIAL TUMOR

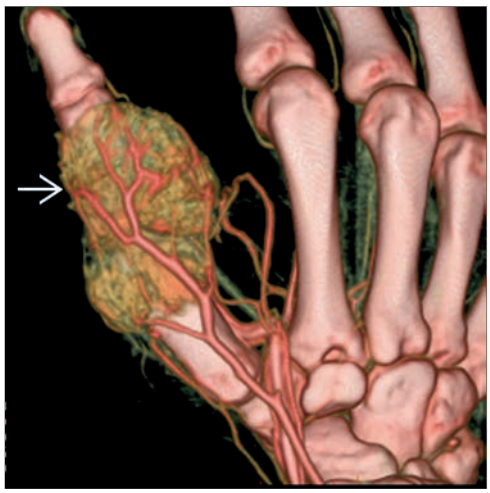
(Left) *Longitudinal ultrasound shows a large, lobulated mass present on the dorsum and ulnar aspect of the thumb base. This mass seems to arise from the metacarpophalangeal joint and encases the extensor pollicis longus tendon.* ***(Right)*** *Transverse ultrasound of the same thumb shows the hypoechoic tumor mass with moderate scalloping of the underlying dorsal aspect of the proximal phalanx.*



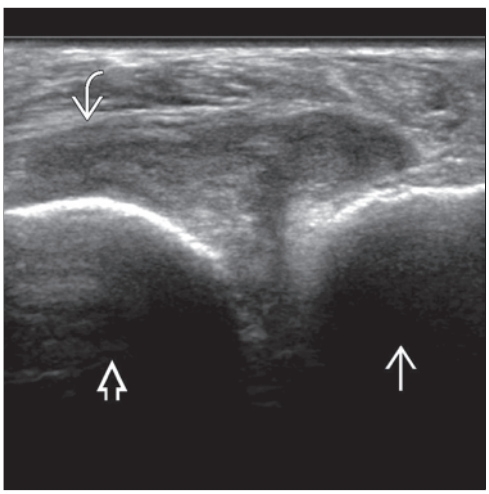


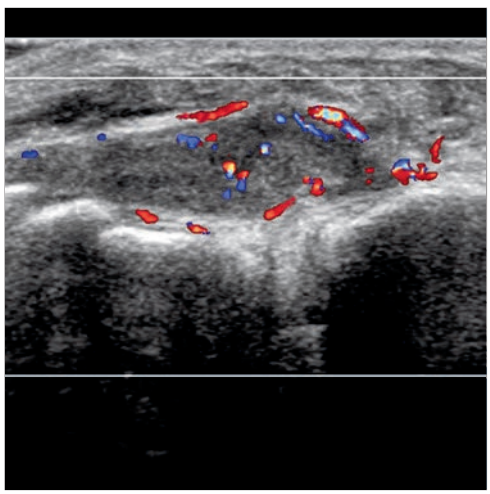
(Left) *Transverse color Doppler ultrasound at the same location shows moderate tumoral hyperemia. The appearances are consistent with PVNS, which was confirmed by ultrasound-guided biopsy (not shown) for histology. Although this tumor probably arose from the metacarpophalangeal joint, the main tumor bulk is extraarticular.* ***(Right)*** *3D CT angiography of the same tumor shows prominent arterial supply to the tumor mass.*

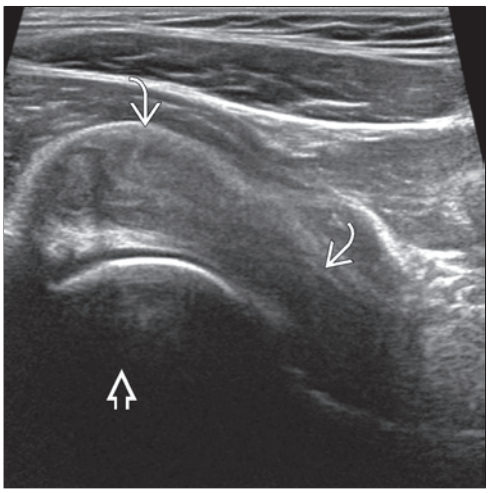


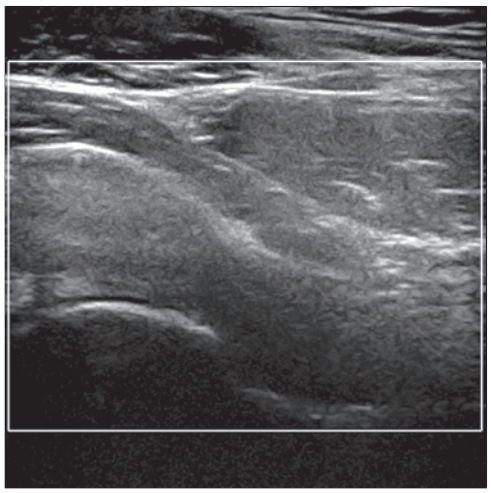


(Left) *Longitudinal ultrasound in a patient with a clinically suspected foot ganglion shows a medium-sized mass communicating the with dorsal aspect of the articulation between the cuboid and lateral cuneiform bones. The mass shows no calcification or cystic component.* ***(Right)*** *Longitudinal color Doppler ultrasound at the same location shows moderate tumoral hyperemia. The overall appearances are consistent with PVNS, confirmed by ultrasound-guided biopsy (not shown) for histology.*

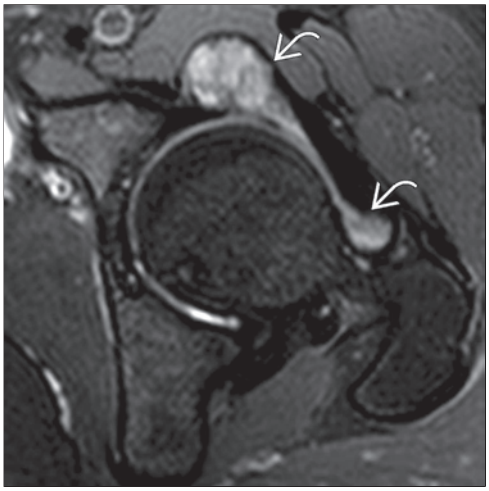


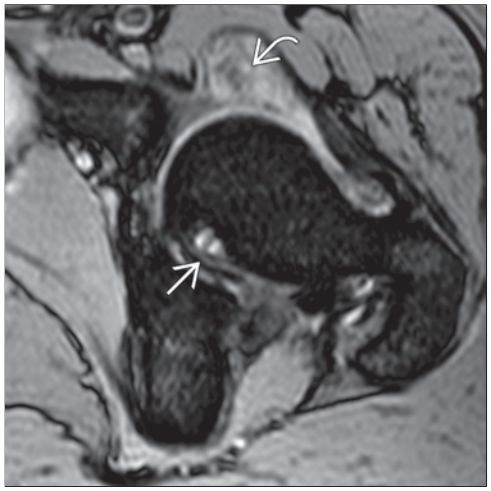




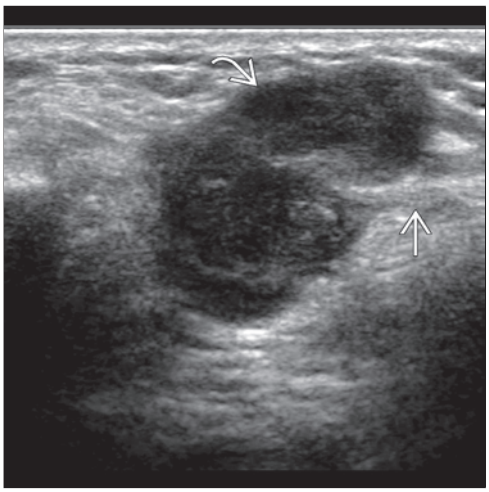


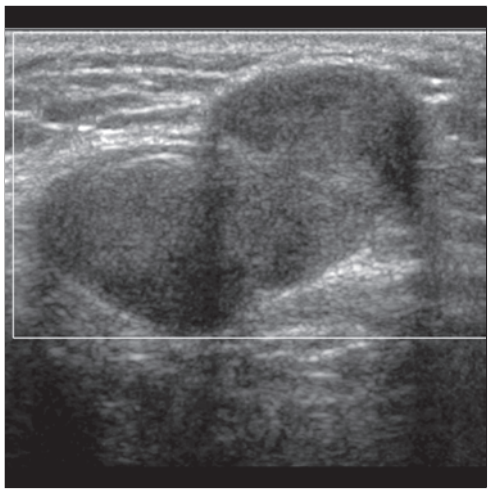
(Left) *Longitudinal ultrasound of a patient with hip pain for 15 months shows localized hypoechoic synovial proliferation on the anterior aspect of the hip. The femoral head is normal. **(Right)** Longitudinal color Doppler ultrasound of the same lesion shows no synovial hyperemia. Nevertheless, this degree of synovial proliferation is most likely due to localized PVNS or focal nodular synovitis.*





(Left) *Axial PD FSE FS MR of the same lesion shows focal nodular synovial proliferation on the anterior aspect of the hip joint. **(Right)** Axial fat-suppressed T2* GRE MR of the same hip shows minimal hemosiderin deposition within the thickened synovium. This is compatible with focal nodular synovitis, which was confirmed by ultrasound-guided biopsy for histology (not shown). There is a small incidental fibrogelatinous cyst posteriorly.*

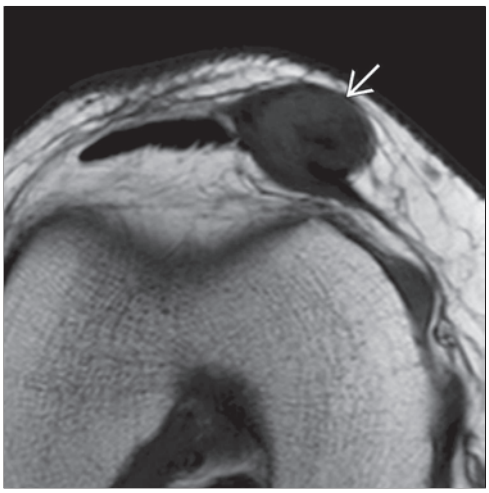




(Left) *Transverse ultrasound in a patient with a knee mass present for 6 months shows a medium-sized soft tissue mass that lies both superficial & deep to the medial patellar retinaculum. Overall appearances favor a focal nodular synovitis. **(Right)** Transverse color Doppler ultrasound of the same tumor shows no tumoral hyperemia. The tumor is still compatible with focal nodular synovitis, which was confirmed by ultrasound-guided biopsy (not shown) for histology.*

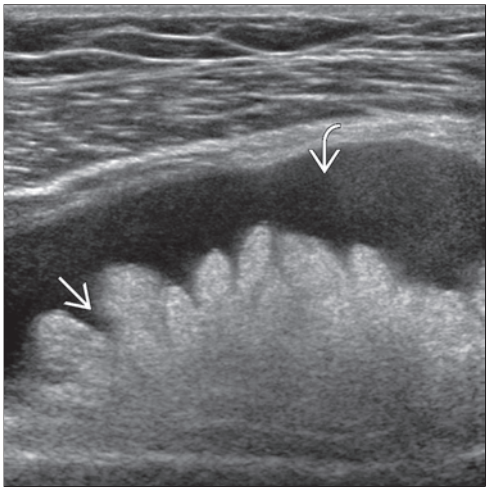
SYNOVIAL TUMOR

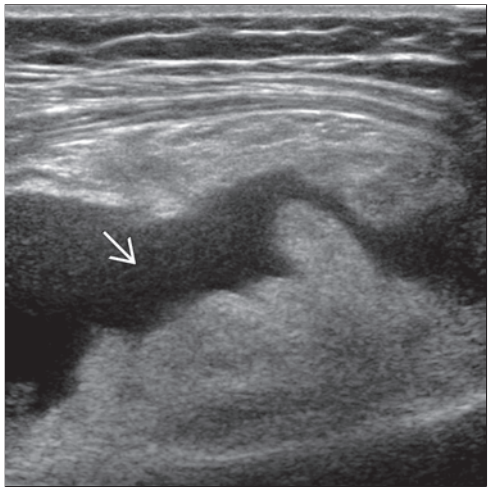
(Left) *Transverse T1WI MR of the same patient as previous image shows a mass with the characteristic hypointensity of focal nodular synovitis extending through and along the medial retinaculum* ⇨. ***(Right)*** *Longitudinal T1WI C+ FS MR of the same tumor shows mild tumoral enhancement* ⇨ *compatible with focal nodular synovitis. One can see that the tumor is straddling the medial retinaculum* ⇨.



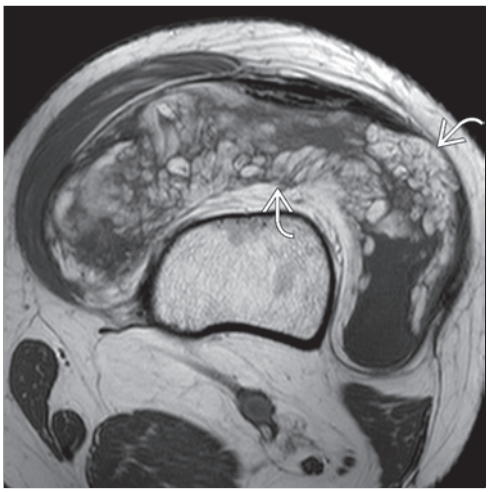


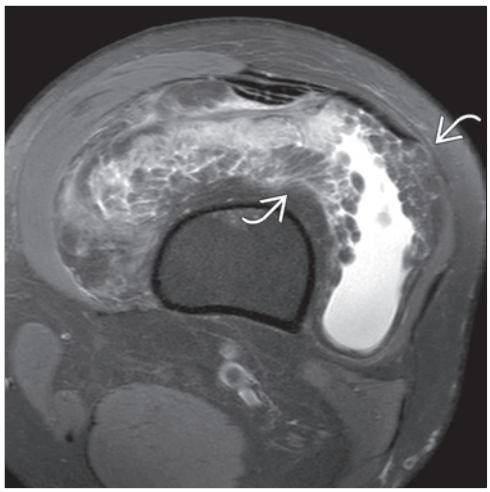
(Left) *Longitudinal ultrasound of a patient with chronic knee swelling shows a large effusion* ⇨ *with severe nodular hyperechoic synovial proliferation* ⇨ *on the posterior aspect of the suprapatellar pouch. No free nodules are present.* ***(Right)*** *Longitudinal ultrasound of the same area shows an additional view of frond-like synovial proliferation* ⇨. *Color Doppler imaging (not shown) revealed minimal hyperemia. Histology from synovectomy revealed features consistent with lipoma arborescens.*

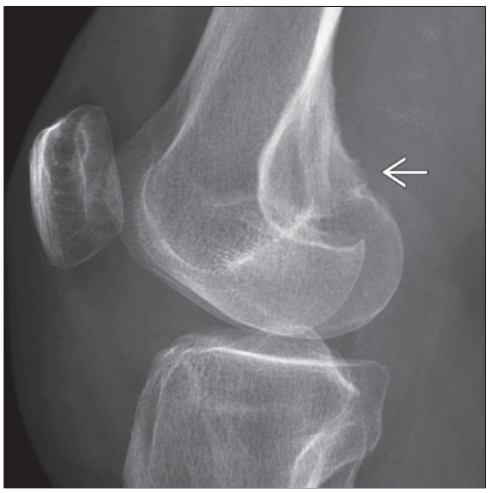


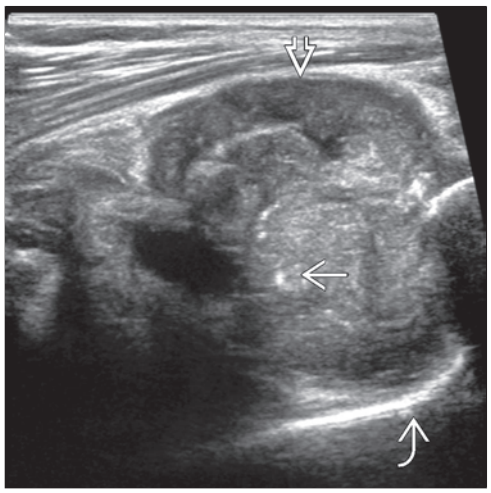


(Left) *Axial T1WI MR of the same lesion shows frond-like synovial proliferation* ⇨ *involving much of the suprapatellar pouch. These fronds have a similar intensity to subcutaneous fat.* ***(Right)*** *Axial fat-suppressed T2WI FS MR of the same lesion shows that the signal within the frond-like projections suppresses* ⇨ *in a similar fashion to subcutaneous fat. This MR appearance is consistent with the histologically confirmed lipoma arborescens.*

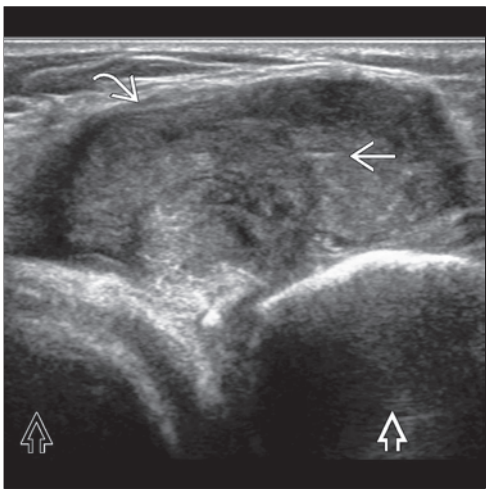


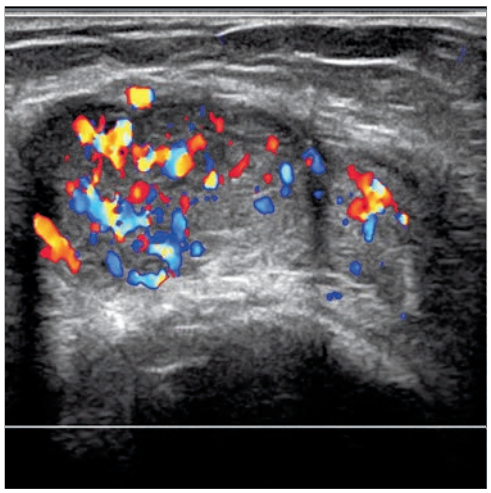




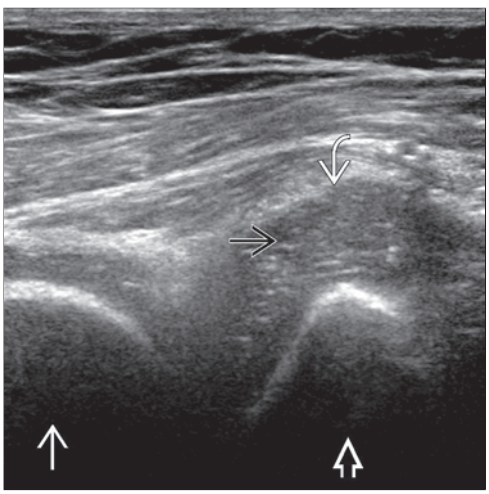


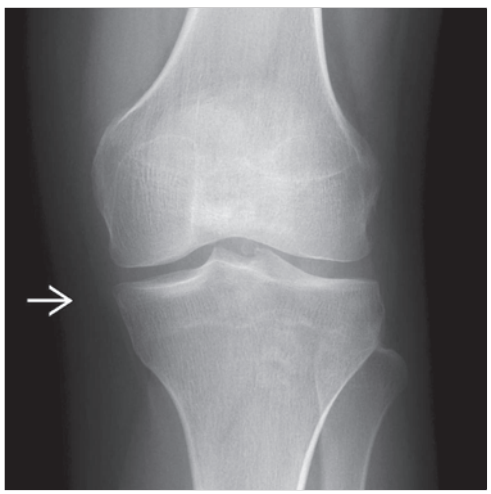
(Left) *Lateral radiograph of the knee in a patient with knee swelling for 20 years shows severe erosion of the posterior aspect of the lateral femoral condyle and supracondylar area.* ***(Right)*** *Longitudinal ultrasound of the same knee shows a large, lobulated mass present on the posterior aspect of the knee joint with dorsal bone scalloping. Although some calcific-type foci are present, this was still considered most likely to be PVNS.*





(Left) *Longitudinal ultrasound of the same patient as previous image shows a separate large, lobulated mass on the medial aspect of the knee. The medial femoral and tibial condyles are normal. There are possibly some calcific foci within the mass.* ***(Right)*** *Transverse color Doppler ultrasound of the same patient shows moderate tumoral hyperemia. The ultrasound diagnosis was PVNS. However, histology following ultrasound-guided biopsy revealed synovial chondrosarcoma.*

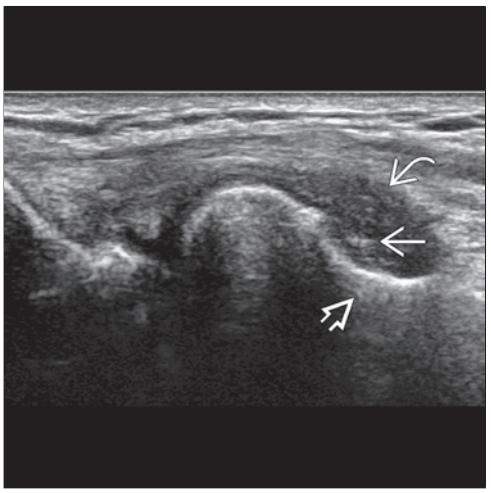


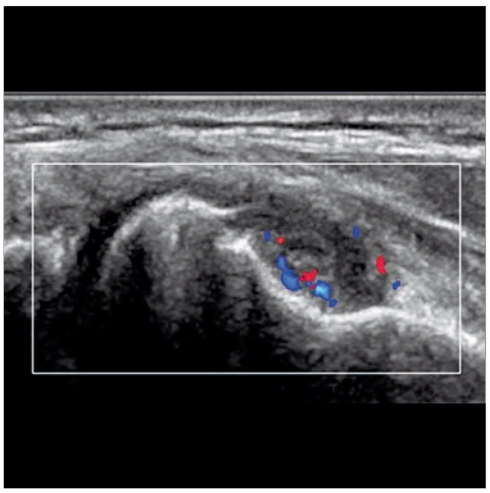


(Left) *Longitudinal ultrasound in a patient with knee pain and swelling for 1 year shows thickened synovial-like tissue containing small echogenic calcific-like foci anteromedially, suspicious of synovial osteochondromatosis. Ultrasound-guided biopsy for histology revealed synovial chondromatosis. The medial femoral and tibial condyles are normal.* ***(Right)*** *Frontal radiograph of the knee of the same patient shows no corresponding soft tissue calcification.*

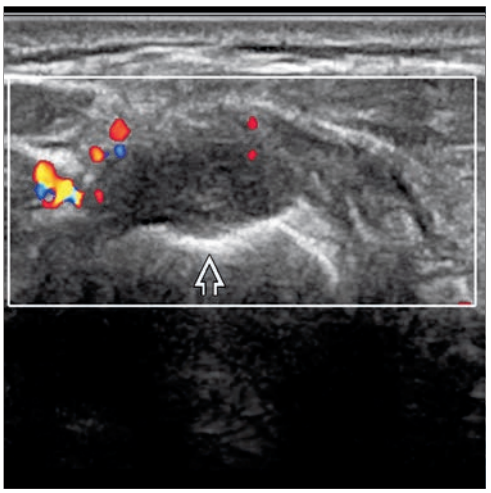
SYNOVIAL TUMOR

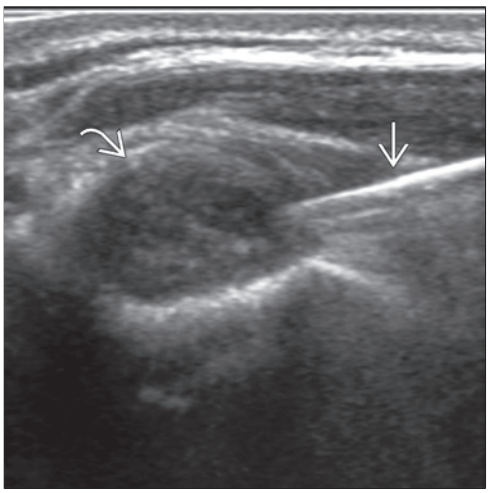
(Left) *Longitudinal ultrasound in a patient with elbow pain and limitation of movement for 1 year shows moderate focal synovial proliferation with early scalloping of the radial neck. There is a suspicion of mild synovial calcification.* ***(Right)*** *Longitudinal color Doppler ultrasound of the same area shows mild synovial hyperemia.*



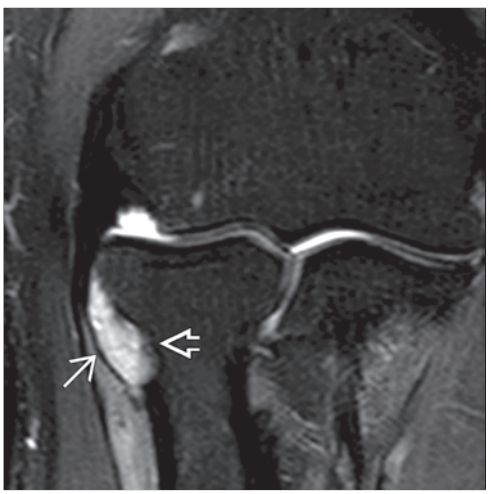


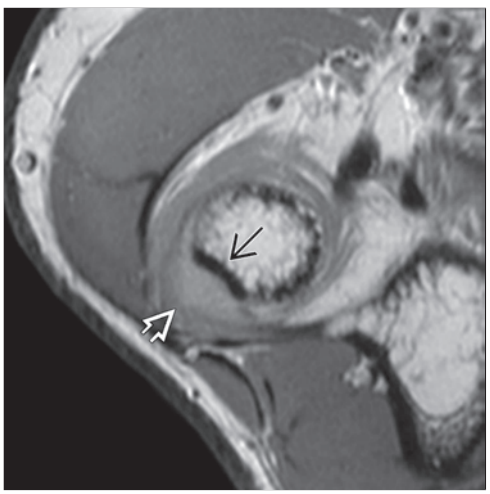
(Left) *Transverse color Doppler ultrasound of the same area shows moderate scalloping of the radial neck.* ***(Right)*** *Transverse ultrasound of the same lesion during ultrasound-guided synovial biopsy shows the coaxial needle at the margin of the tumor prior to introduction of the Tru-Cut needle. Histology revealed synovial chondromatosis. As the ultrasound appearances are not entirely specific, biopsy is indicated to confirm diagnosis in most synovial tumors.*



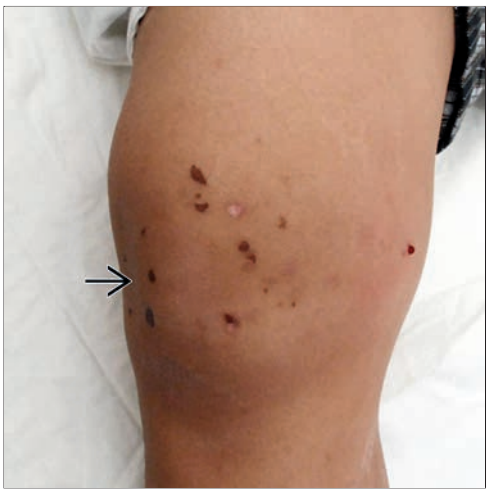


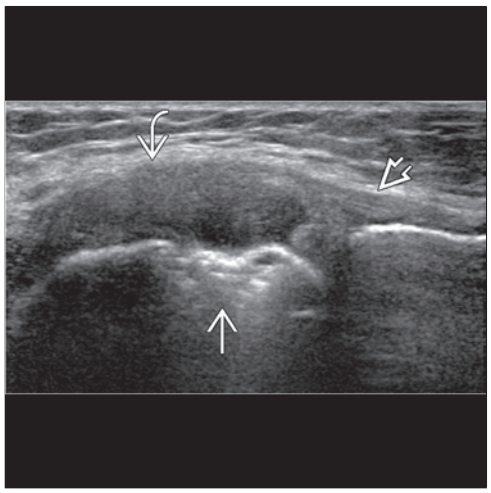
(Left) *Coronal T2WI FS MR of the same elbow shows the synovial chondromatosis tumor deep to the radial collateral ligament with moderate scalloping of the radial neck.* ***(Right)*** *Transverse PDWI MR of the same elbow shows moderate focal synovial thickening secondary to synovial chondromatosis with scalloping of the posterior aspect of the radial neck. One can appreciate the strong correlation between the MR and ultrasound appearances.*



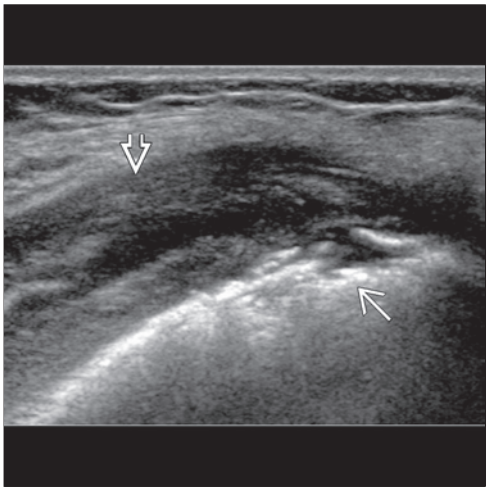


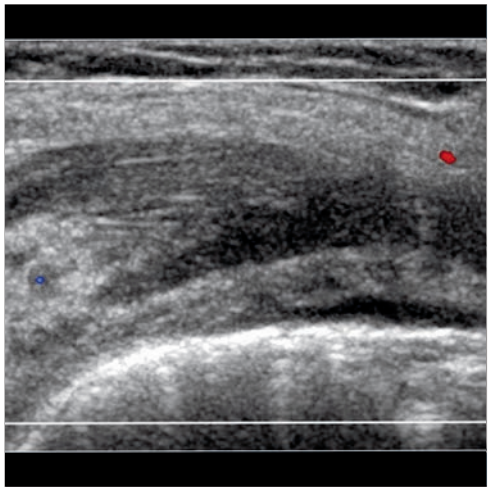
SYNOVIAL TUMOR



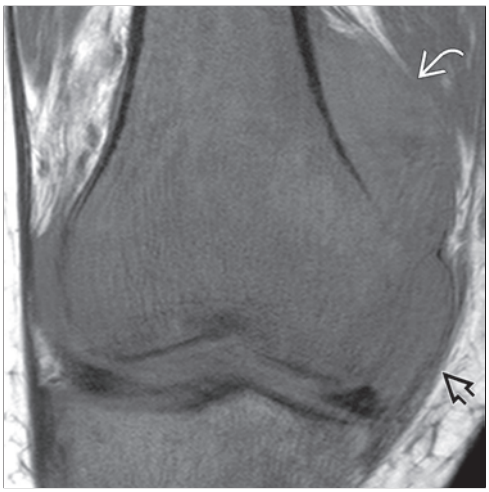


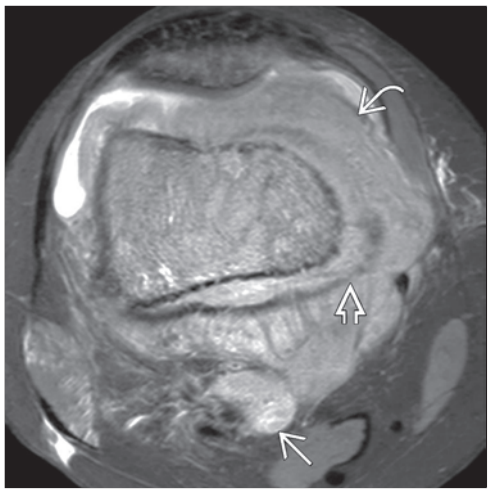
(Left) *Clinical photograph of an otherwise healthy patient with knee pain and swelling after minor sprain 1 month earlier shows some skin petechiae* ⇨. ***(Right)*** *Longitudinal ultrasound of the medial aspect of the knee in the same patient shows severe synovial-like thickening* ⇨ *elevating the medial collateral ligament* ⇨ *with moderate cortical resorption of the medial femoral condyle* ⇨.





(Left) *Transverse ultrasound of the same knee as previous image shows markedly thickened knee synovium* ⇨, *a small knee joint effusion with additional cortical resorption of the anterior aspect of the medial femoral condyle* ⇨. ***(Right)*** *Transverse color Doppler ultrasound of the same area shows no demonstrable hyperemia. The provisional ultrasound diagnosis was tuberculous septic arthritis; however, ultrasound-guided biopsy for histology revealed diffuse large B-cell non-Hodgkin lymphoma.*



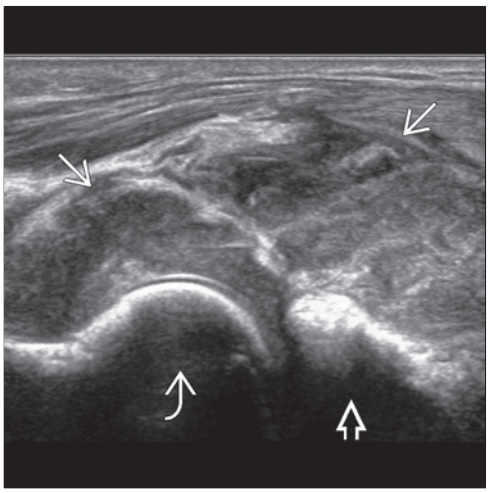


(Left) *Subsequent coronal T1WI MR of the same knee shows a very hypercellular marrow* ⇨ *with cortical resorption and a large soft tissue mass on the medial aspect of the knee, deep to the medial collateral ligament* ⇨. ***(Right)*** *Axial T2WI FS MR of the same knee shows the lymphomatous mass* ⇨ *extending from the medial distal femur with cortical resorption and severe periosteal thickening* ⇨. *There is an enlarged popliteal lymph node* ⇨.

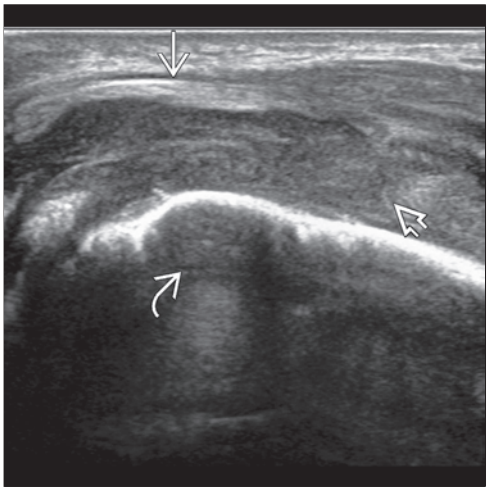
SYNOVIAL TUMOR

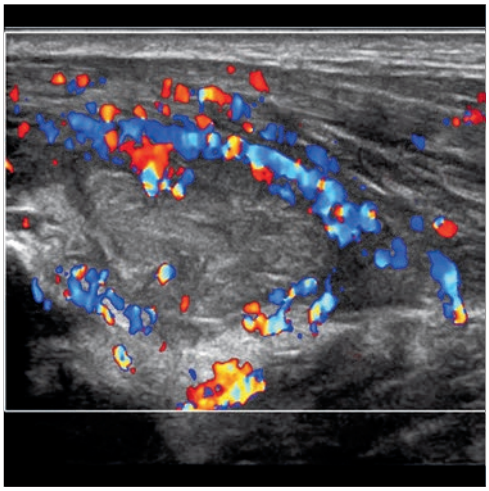
(Left) *Frontal radiograph of the elbow in a patient with elbow pain following mild trauma shows moderate periarticular osteopenia with generalized loss of cortical definition as well as early marginal erosions.* ***(Right)*** *Longitudinal ultrasound of the anterior elbow of the same patient shows a large, synovial-type mass on the anteromedial aspect of the elbow. No calcific foci are evident, and there is no joint effusion. The trochlea and coronoid process are normal.*





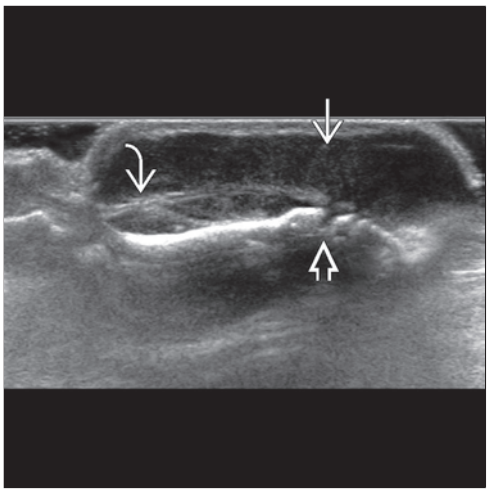
(Left) *Longitudinal ultrasound of the posteromedial aspect of the elbow joint of the same patient shows hypoechoic synovial proliferation deep to the triceps tendon. The distal humerus is normal.* ***(Right)*** *Transverse color Doppler ultrasound of the posterior aspect of the elbow of the same patient shows severe marginal synovial hyperemia. The appearance would fit a diagnosis of PVNS, though the location of erosions would be atypical. Percutaneous biopsy revealed tuberculous infection.*

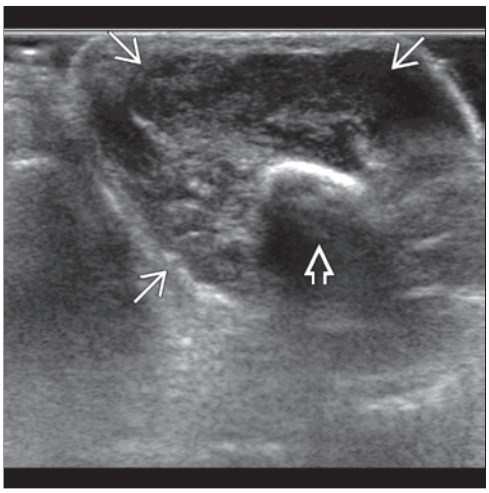


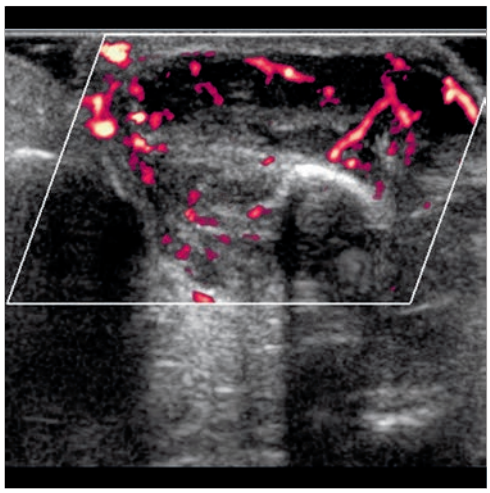


(Left) *Clinical photograph shows a patient with a little toe mass enlarging for 4 years. The skin marker represents the planned line of surgical incision.* ***(Right)*** *Longitudinal ultrasound of the same patient shows a hypoechoic dorsal mass surrounding the extensor digitorum tendon. This tendon does not have a tendon sheath. Histology following percutaneous biopsy revealed PVNS. This extraarticular PVNS most likely arose from the metatarsophalangeal joint.*



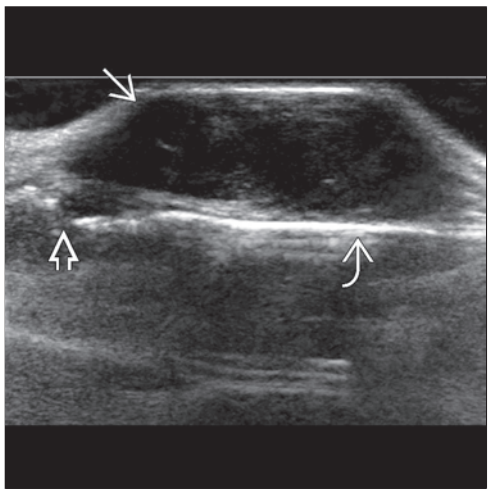




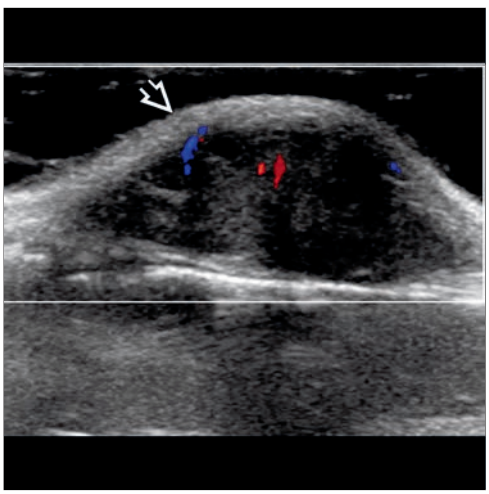


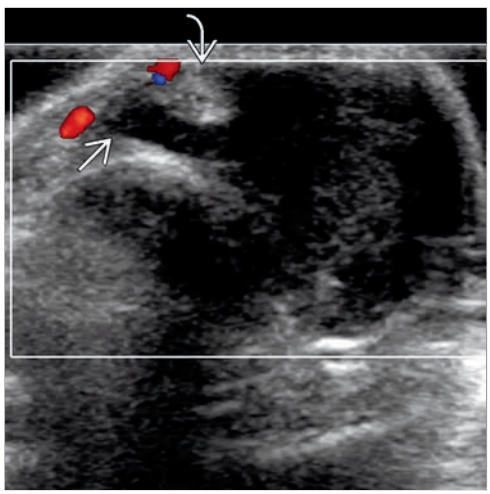
(Left) *Transverse ultrasound of the same tumor as previous image shows the hypoechoic extraarticular PVNS surrounding the dorsal, medial, & lateral aspects of the proximal phalanx.* ***(Right)*** *Transverse power Doppler ultrasound of the same location shows moderate hyperemia of an extraarticular PVNS tumor. Although extraarticular PVNS tumors may lie in contact with tendons, this does not necessarily imply that they arose from these tendons.*



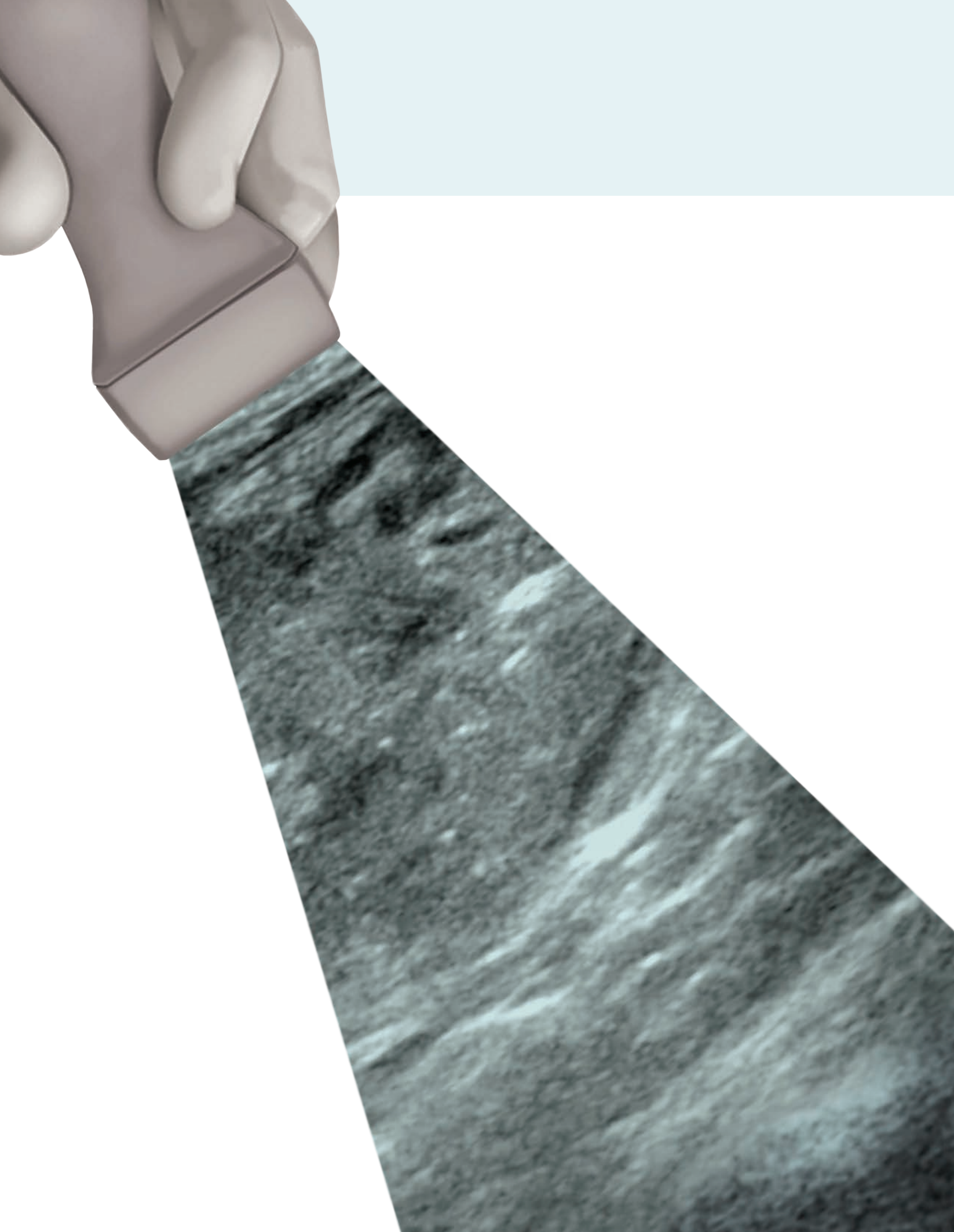


(Left) *Clinical photograph shows a patient with a slowly growing middle finger mass, which had been present for 18 months.* ***(Right)*** *Transverse ultrasound in the same patient shows a medium-sized mass on the dorsoradial aspect of the proximal phalanx in contact with the proximal interphalangeal joint. The appearances are consistent with PVNS, which was confirmed on histology following ultrasound-guided biopsy. This is an extraarticular PVNS which most likely arose from the PIP joint.*





(Left) *Longitudinal color Doppler ultrasound of the same tumor as previous image shows mild tumoral hyperemia. Note that lifting the transducer from the tumor to assess hyperemia positively alters the tumor shape.* ***(Right)*** *Transverse color Doppler ultrasound of the same tumor shows the tongue of the tumor extending deep to the extensor digitorum tendon. This tendon does not have a synovial sheath, & though close to the tendon, this tumor most likely arose from the interphalangeal joint.*



SECTION 8

Soft Tissue and Bone Tumors

Plantar Fasciitis and Fibromatosis **II**-8-2
Lipoma **II**-8-8
Epidermoid Cyst **II**-8-16
Pilomatricoma **II**-8-22
Dermatofibrosarcoma Protuberans **II**-8-26
Vascular Leiomyoma **II**-8-30
Superficial Metastases, Lymphoma, and Melanoma . . **II**-8-34
Vascular Anomaly **II**-8-40
Foreign Body and Injection Granulomas **II**-8-48
Lymph Node Abnormality **II**-8-56
Soft Tissue Sarcoma **II**-8-62
Bone Tumor **II**-8-70
Local Tumor Recurrence **II**-8-82

PLANTAR FASCIITIS AND FIBROMATOSIS

Key Facts

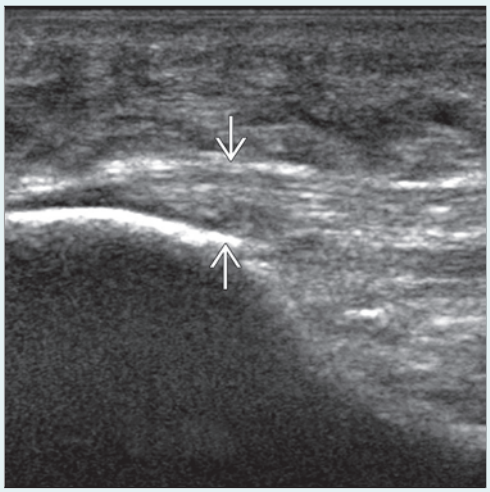
Imaging

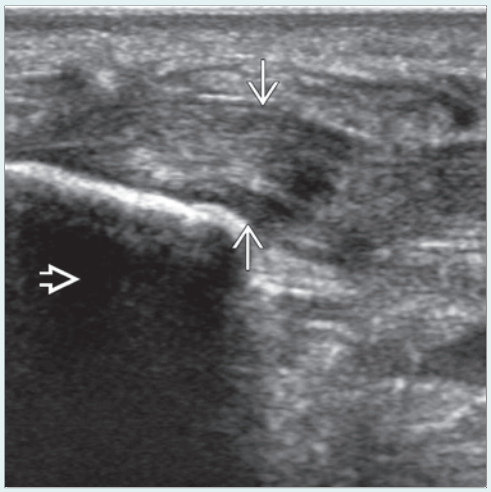
- **Plantar fasciitis**
  - Thickened plantar fascial insertion, especially at medial aspect of calcaneum
  - Plantar fascia thickness > 4.5 mm (most useful sign)
  - ± hypoechogenicity of plantar fascia
  - ± decreased fascial definition
  - ± perifascial edema
  - Spur is located deep to (& not within) fascia
  - Spur may simulate anterior edge of calcaneus
  - Plantar fasciitis bilateral in 1/3
  - Subclinical disease on opposite side is not uncommon; do not use opposite side as internal normal reference
- **Plantar fibromatosis**
  - Discrete fusiform-shaped nodule of plantar fascia separated from calcaneal insertion: Located within plantar fascia
  - Hypoechoic to plantar fascia (75%)
  - Isoechoic to plantar fascia (25%)
  - Posterior acoustic enhancement (40%), shadowing (20%)
  - Intrinsic vascularity (10%)
  - Majority are located within medial or central bands of plantar fascia
  - Often multiple; bilateral in 1/3

Diagnostic Checklist

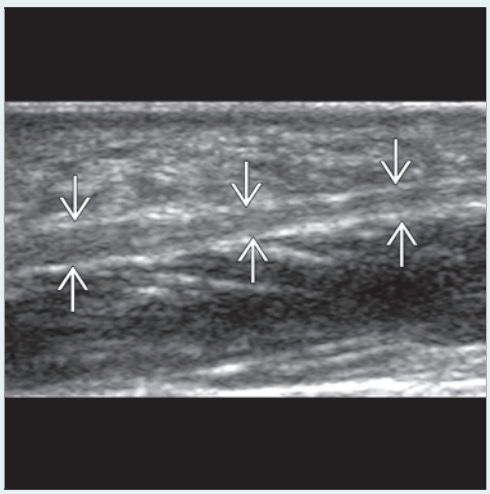
- Likelihood of plantar fascitis increases with increasing thickness of fascia at calcaneal insertion
- MR if ultrasound is negative for plantar fasciitis (to exclude other causes of heel pain)
- Plantar fibromatosis = distinct plantar fascial nodule separate from calcaneal insertion
- Consider aggressive plantar fibromatosis if plantar fascia nodule has infiltrative superficial or deep margins (relatively rare tumor)

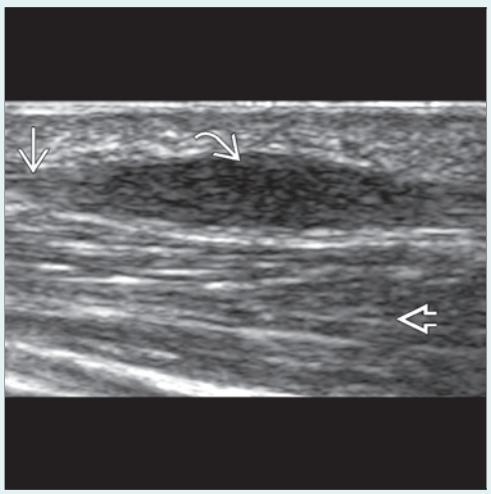
(Left) *Longitudinal ultrasound shows the normal plantar fascia ⇨ at the calcaneal insertion. This plantar fascia measures 3 mm thick. Measurements of plantar fascial thickness should be made toward the medial side of the calcaneum.* ***(Right)*** *Longitudinal ultrasound shows severe thickening (8 mm) of the plantar fascia ⇨ at the calcaneal insertion consistent with plantar fasciitis. Measurements are made at the distal edge of the calcaneum ⇨ medially.*





(Left) *Longitudinal ultrasound shows the normal plantar fascia ⇨ at the midfoot level.* ***(Right)*** *Longitudinal ultrasound of the midfoot region shows a well-defined, fusiform-shaped hypoechoic nodule ⇨ arising from the plantar fascia ⇨ consistent with plantar fibromatosis. Note the minimal posterior acoustic enhancement deep to the fibroma ⇨.*





PLANTAR FASCIITIS AND FIBROMATOSIS

TERMINOLOGY

Synonyms
- Plantar fasciitis: Jogger's heel, tennis heel, policeman's heel, heel spur syndrome, calcaneal spur syndrome
- Plantar fibromatosis: Ledderhose disease, plantar fibroma

Definitions
- Plantar fasciitis: Degeneration ± chronic inflammation ± fibroblastic proliferation of plantar fascia insertion to medial tuberosity of calcaneus
- Plantar fibromatosis: Nodular fibroblastic proliferation of plantar fascia separate from calcaneus

IMAGING

General Features
- Best diagnostic clue
  - Plantar fasciitis: Thickened plantar fascial insertion
  - Plantar fibromatosis: Nodular thickening of plantar fascia
- Location
  - Plantar fasciitis: Medial tuberosity calcaneus
    - Bilateral in 1/3
  - Plantar fibromatosis: Affects medial (60%) or central bands (40%) of plantar fascia
    - Several nodules may coexist on same side
    - Bilateral in 1/3
- Size
  - Plantar fasciitis: Fascial thickness > 4.5 mm
  - Plantar fibromatosis
    - Average length: 13 mm (range: 4-17 mm)
    - Average width: 10 mm (range: 4-22 mm)
    - Average depth: 4 mm (range: 2-10 mm)
- Morphology
  - Plantar fasciitis: Fascial thickening at calcaneal insertion
  - Plantar fibromatosis: Discrete well-defined nodule within plantar fascia

Radiographic Findings
- Radiography
  - Plantar fasciitis: Plantar calcaneal spur present in ~ 50% of patients with plantar fasciitis
    - Also found in asymptomatic subjects
    - Consider enthesopathy when fluffy periostitis, erosion, & sclerosis are present

MR Findings
- T1WI
  - Plantar fasciitis: Hypo - or isointense thickening of plantar fascia at calcaneal insertion
  - Plantar fibromatosis: Isointense nodule along plantar fascia
- T2WI
  - Plantar fibromatosis: Hypo- to isointense nodule along plantar fascia
- STIR
  - Plantar fasciitis
    - Thickness > 4.5 mm (almost 100%)
    - Subcutaneous or perifascial edema (90%)
    - Insertional bone marrow edema (40%)
    - Markedly increased insertional marrow edema, erosions, & sclerosis suggest an inflammatory enthesopathy (associated with spondyloarthropathy)

Ultrasonographic Findings
- **Plantar fasciitis**
  - Plantar fascia thickness > 4.5 mm (most useful sign)
  - ± hypoechogenicity of plantar fascia
  - ± minor calcification of fascia
  - ± lack of fascial definition
  - ± perifascial edema
  - ± mild fascial hyperemia
  - Calcaneal spur
    - Spur is located deep to (& not within) fascia
    - May simulate anterior edge of calcaneus
- **Plantar fibromatosis**
  - Discrete fusiform-shaped nodule of plantar fascia separated from calcaneal insertion
  - Hypoechoic to plantar fascia (75%)
    - Isoechoic to plantar fascia (25%)
  - Posterior acoustic enhancement (40%), shadowing (20%)
  - Intrinsic vascularity (10%)
  - Majority are located within midsubstance or plantar aspect of plantar fascia
    - If nodule is large & has infiltrative superficial or deep margin, consider aggressive plantar fibromatosis (relatively rare tumor)
  - Coexistent thickening of ipsilateral calcaneal insertion present in 1/3 of patients without related symptoms

Nuclear Medicine Findings
- Bone scan
  - Plantar fasciitis: Positive in 60-98% of cases
    - Increased blood flow ± blood pooling ± increased activity on delayed images

Imaging Recommendations
- Best imaging tool
  - Plantar fasciitis & fibromatosis; ultrasound is accurate, quick, & accessible
- Protocol advice
  - Examine fascia in transverse & longitudinal planes
    - Routinely examine both sides as subclinical contralateral disease is common in both diseases
  - Measure depth of fascia at medial leading edge of calcaneum
  - Avoid excessive transducer pressure as this will efface perifascial edema & blanch color Doppler signal

DIFFERENTIAL DIAGNOSIS

Subcutaneous Fat Necrosis
- Focal subcutaneous edema ± swelling
- Trauma history

Calcaneal Stress or Insufficiency Fracture
- Stress fracture: Abnormal stress on normal bone
- Insufficiency fracture: Normal stress on abnormal bone
- Best assessed by MR

PLANTAR FASCIITIS AND FIBROMATOSIS

Plantar Bursitis
- Fluid-filled bursa or flat hypoechoic area superficial to plantar fascia
- Typically forefoot region under metatarsal heads

Plantar Fascial Tear
- Trauma history
- Fascial discontinuity ± swelling, edema, or hemorrhage

PATHOLOGY

General Features
- Etiology
  - Plantar fasciitis: Possibly caused by repetitive microtrauma or microvascular injury
  - Plantar fibromatosis: Unknown etiology; not knowingly related to trauma
    - Possibly genetic
    - Possibly related to collagen profile
- Associated abnormalities
  - May be related to other fibroproliferative diseases (Dupuytren contracture, Peyronie disease, etc.)
    - Onset of other fibromatoses may be delayed for 5-10 years after onset of plantar fibromatosis
- Plantar fascia = multilayered fibrous aponeurosis, 1-2 mm thick, with medial, central, & lateral bands
  - Central band is largest; originates from medial calcaneal tuberosity
  - Divides in forefoot into 5 bands that insert onto plantar plates of metatarsophalangeal joints & bases of proximal phalanges

Gross Pathologic & Surgical Features
- Plantar fasciitis: Firm thickening of plantar fascia at calcaneal insertion
- Plantar fibromatosis: Firm whitish nodule

Microscopic Features
- Plantar fasciitis: Degeneration of plantar fascia ± fibroblastic proliferation ± chronic inflammatory change
- Plantar fibromatosis: 3 phases of fibroblastic proliferation within plantar fascia
  - Proliferative phase: Nodular fibroblastic proliferation
  - Active phase: Collagen synthesis & deposition
  - Mature phase: Reduced fibroblastic proliferation, collagen maturation

CLINICAL ISSUES

Presentation
- Most common signs/symptoms
  - Plantar fasciitis: Heel pain ↑ by weightbearing
    - Pain worse on 1st few steps in morning
  - Plantar fibromatosis: Sole pain ± palpable firm lump
    - Pain ↑ by prolonged weightbearing
- Clinical profile
  - Plantar fasciitis: Tenderness on deep palpation anterior to medial calcaneal tuberosity
  - Plantar fibromatosis: Sole lump usually nontender or mildly tender attached to plantar fascia

Demographics
- Age
  - Plantar fasciitis: 40-60 years
    - Younger in predisposed individuals (runners, military personnel)
    - Reduced ankle dorsiflexion, prolonged weightbearing and increased body weight are all risk factors
  - Plantar fibromatosis: 50 years (range: 30-80 years)
- Gender
  - Plantar fasciitis & fibromatosis: M:F = 1:1
- Epidemiology
  - Plantar fasciitis: Most common cause of heel pain
    - 10% of running injuries (excessive running, faulty shoes, running on uneven surfaces, high-arched foot or short Achilles tendon)
    - Additional risk factors: Obesity, prolonged weightbearing, pes planus
  - Plantar fibromatosis: Less common than plantar fasciitis
    - No specific risk factors identified

Natural History & Prognosis
- Plantar fasciitis
  - Symptoms resolve in 80% within 12 months
- Palmar fibromatosis
  - Similar tendency to improve with time
    - Nodules become smaller & lesser painful

Treatment
- Plantar fasciitis
  - Conservative: Start treatment soon after onset
    - Anti-inflammatory agents
    - ± padding & strapping, shoe inserts
    - ± stretching of plantar fascia
    - ± night splints to keep ankle in neutral position
  - Steroid ± long-acting local anesthetic injection
    - Usually not possible to inject directly into plantar fascia; instead, inject into perifascial tissues
    - Only temporary relief for ~ 4 weeks
  - Extracorporeal shockwave therapy
  - Surgery (for patients with persistent symptoms)
    - Open or endoscopic release of plantar fascia
- Plantar fibromatosis
  - Conservative
    - Shoe inserts
    - ± steroid ± long-acting local anesthetic injection
  - Surgery (for very painful nodules)
    - Recurrence common after surgery

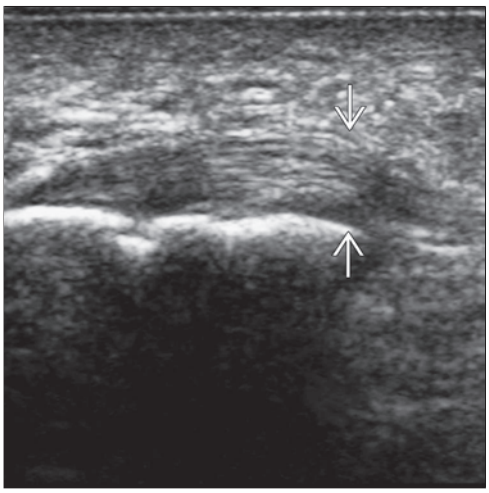
DIAGNOSTIC CHECKLIST

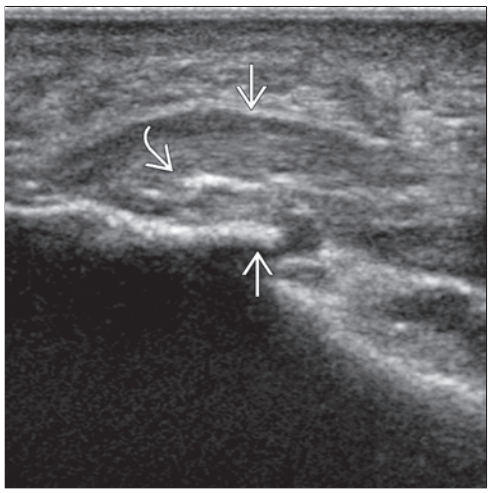
Consider
- Aggressive plantar fibromatosis if plantar fascia nodule has infiltrative superficial or deep margins (rare)

Image Interpretation Pearls
- Likeliness of fasciitis increases with increasing thickness of plantar fascia at calcaneal insertion
- Plantar fibromatosis = distinct plantar fascial nodule separate from calcaneal insertion

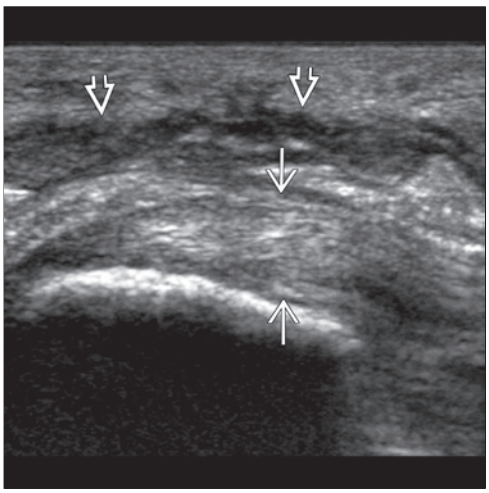
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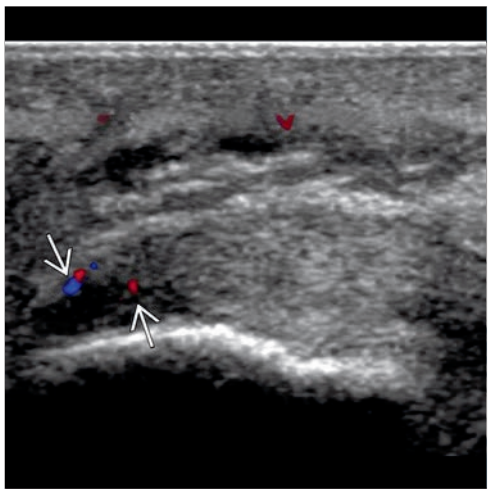
1. Ieong E et al: Ultrasound scanning for recalcitrant plantar fasciopathy. Basis of a new classification. Skeletal Radiol. 42(3):393-8, 2013





(Left) *Longitudinal ultrasound shows mild thickening (5 mm) of plantar fascia at medial calcaneal insertion, consistent with mild plantar fasciitis.* ***(Right)*** *Longitudinal ultrasound shows severe thickening (10 mm) of the plantar fascia with intrinsic calcification at the medial calcaneal insertion, consistent with plantar fasciitis. Note the small osteophytic plantar calcaneal spur. These spurs occur deep to, rather than within, the plantar fascia.*





(Left) *Longitudinal ultrasound shows moderate thickening (7 mm) of the plantar fascia at the medial calcaneal insertion. There is marked perifascial edema. This perifascial edema is not a common finding.* ***(Right)*** *Longitudinal color Doppler ultrasound of the same patient shows mild increase in vascularity of the plantar fascia at the calcaneal insertion.*

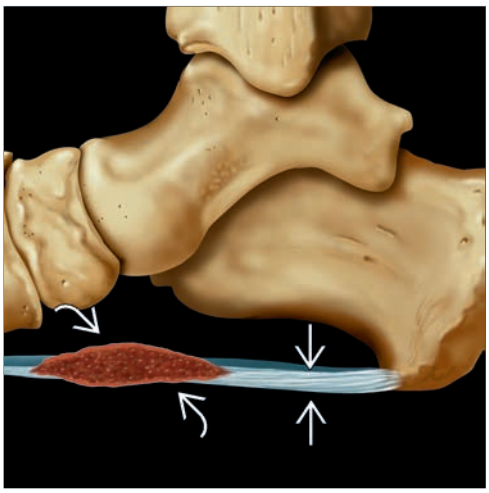




(Left) *Sagittal T2WI FS MR shows mild thickening (5 mm) of the plantar fascia at the medial calcaneal insertion. There is mild perifascial edema and mild adjacent subcortical bone marrow edema.* ***(Right)*** *Coronal T2WI FS MR of the same patient shows thickening of the plantar fascia at the medial calcaneal insertion. There is mild perifascial edema and mild subfascial bone marrow edema.*

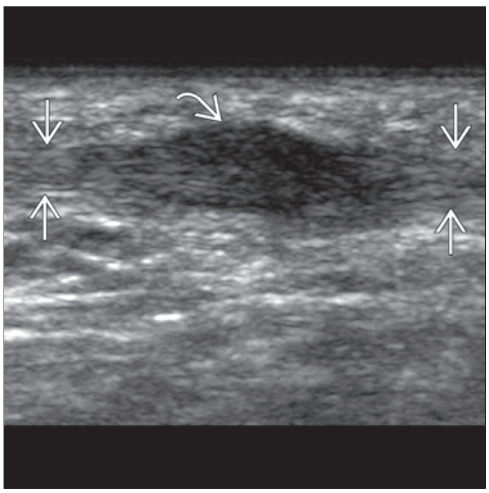
PLANTAR FASCIITIS AND FIBROMATOSIS

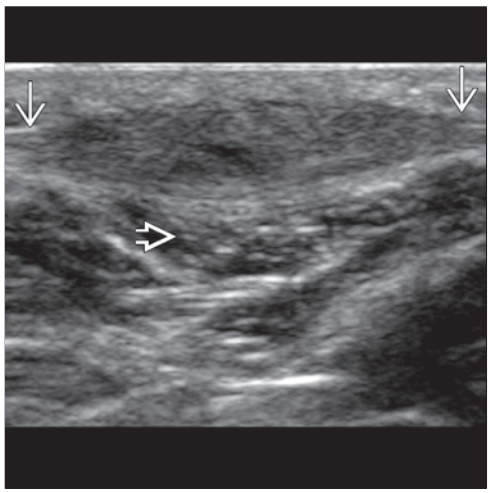
(Left) *Longitudinal graphic shows a large plantar fibroma arising from the plantar fascia. **(Right)** Clinical photograph shows a solitary small nodule due to a plantar fibroma on the medial aspect of the midsole. Most plantar fibromas occur in the midfoot region and are often multiple and bilateral.*



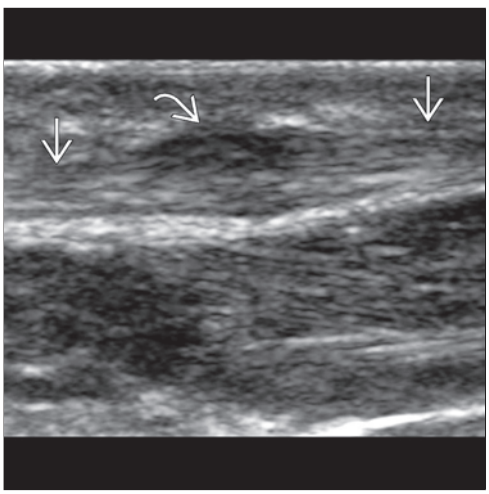


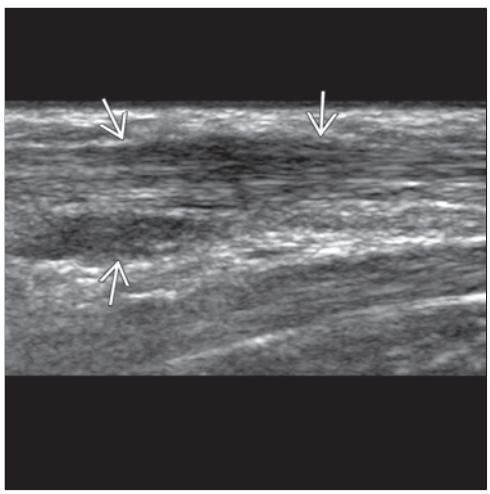
(Left) *Longitudinal ultrasound shows a hypoechoic nodule arising from the plantar fascia, consistent with plantar fibromatosis. **(Right)** Longitudinal ultrasound shows a larger fusiform-shaped isoechoic plantar fibroma arising from the plantar fascia. Note indentation of the underlying muscle.*



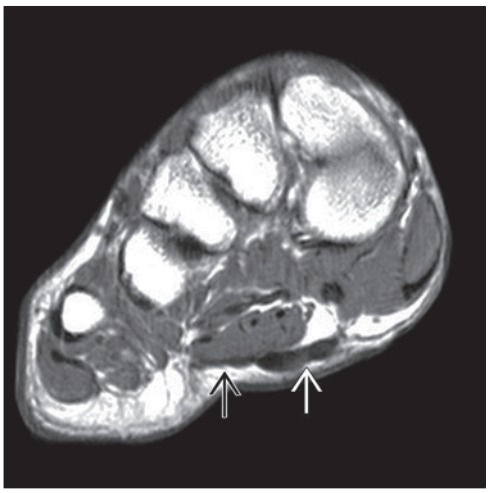


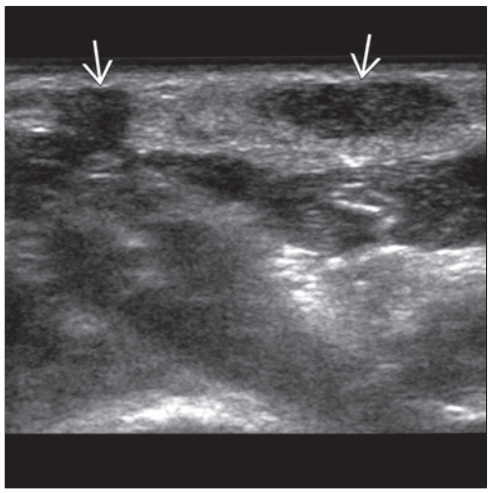
(Left) *Longitudinal ultrasound shows a small plantar fibroma arising from the plantar fascia. This plantar fibroma primarily only affects the superficial fibers of the plantar fascia. **(Right)** Longitudinal ultrasound shows a larger ill-defined plantar fibroma. The fibroma is hypoechoic and is less well defined, tending to insinuate along the plantar fascia.*



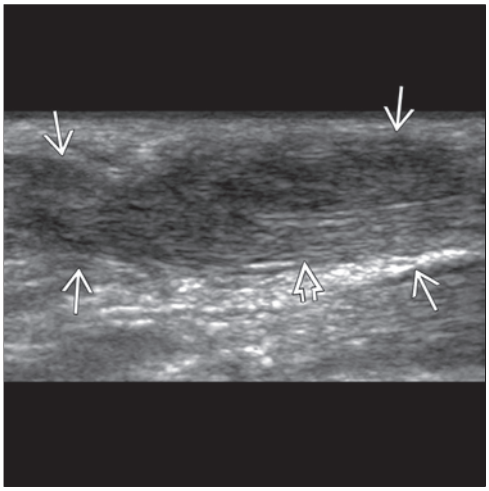


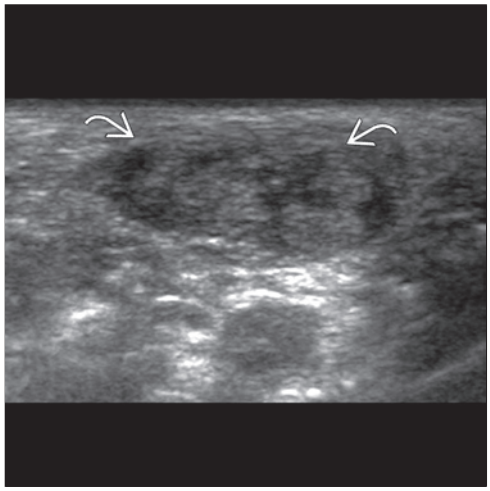
PLANTAR FASCIITIS AND FIBROMATOSIS



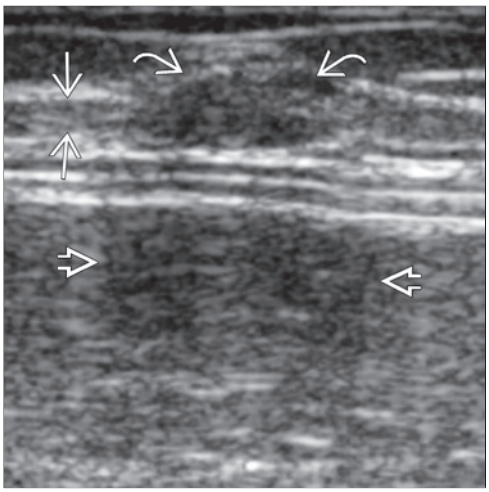


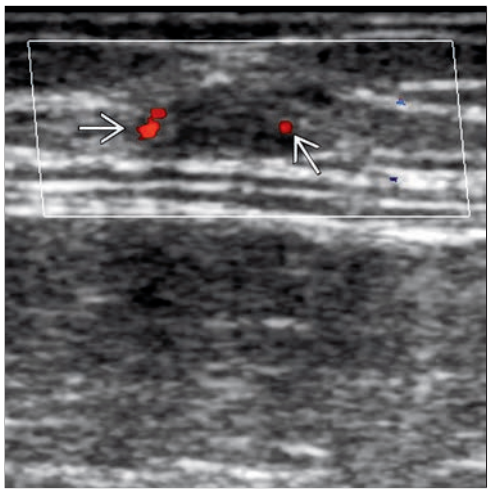
(Left) *Coronal T1WI MR shows localized nodular thickening of the medial band of the plantar fascia in the midfoot region consistent with plantar fibromatosis. The lateral band of the plantar fascia is not thickened. **(Right)** Transverse ultrasound shows 2 well-defined, hypoechoic plantar fibromas arising from the same plantar fascia. When you locate 1 plantar fibroma, always check for others as they are commonly multiple and bilateral.*





(Left) *Longitudinal ultrasound shows a large, diffuse, ill-defined, hypoechoic plantar fibroma. The fibroma is extending along the plantar fascia but not extending deep into the foot. **(Right)** Transverse ultrasound of the same lesion shows an oval-shaped, heterogeneous, echogenic plantar fibroma. Most plantar fibromas are smaller than this example.*





(Left) *Longitudinal ultrasound shows a small plantar fibroma arising from the plantar fascia. Note the posterior acoustic shadowing. Plantar fibromas may show either acoustic shadowing or enhancement. **(Right)** Longitudinal color Doppler ultrasound of the same fibroma shows minimal internal vascularity. Most plantar fibromas do not show demonstrable vascularity on color Doppler imaging.*

LIPOMA

Key Facts

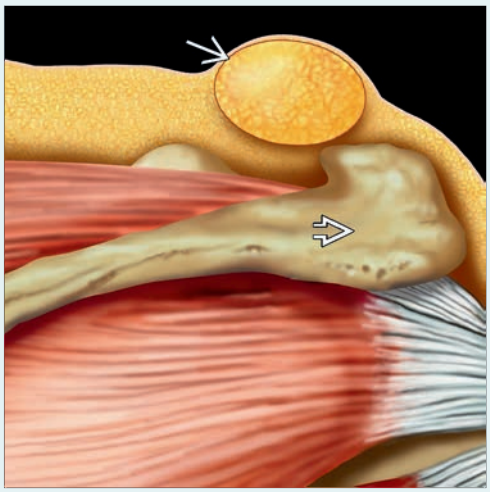
Imaging
- Subcutaneous, most common
- Well-defined, oblong-shaped encapsulated mass with fine linear striations parallel to long axis of tumor
  - Of variable echogenicity depending on cellularity & fat-water content
- Absent or minimal internal vascularity on color Doppler imaging
- Compressible similar to adjacent fat
- Subfascial lipomas are more variable in appearance
  - Nevertheless, appearance is usually sufficiently specific to enable ultrasound diagnosis

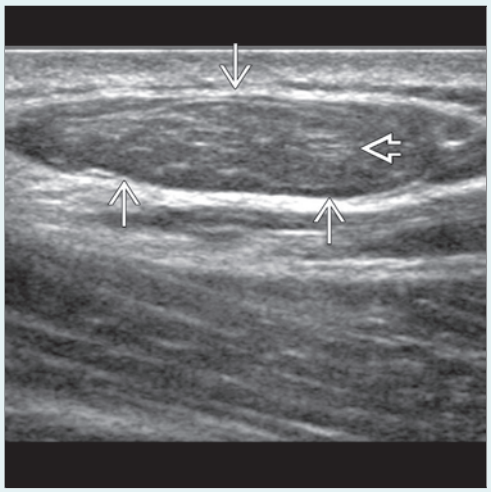
Pathology
- Lipoma fat is similar to normal body fat

Clinical Issues
- Most common soft tissue tumor
- Soft, well-defined, painless mass enlarging over months, often during period of weight gain

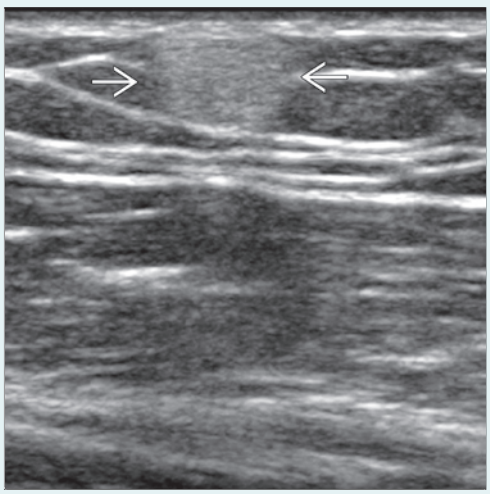
Diagnostic Checklist
- Ultrasound findings are usually characteristic
- Fine internal striations parallel to long axis of tumor = most characteristic US finding
- MR is useful for assessment of large, deep-seated lipomas
- MR is better than ultrasound at differentiating between benign or malignant lipomas
  - Large size, deep location, & heterogeneity are best indicators of liposarcoma
  - However, not all heterogeneity within lipoma necessarily implies liposarcoma
  - Calcification, small nonfatty areas, myxoid tissue, & fat necrosis can be features of atypical lipoma & are not necessarily diagnostic of liposarcoma

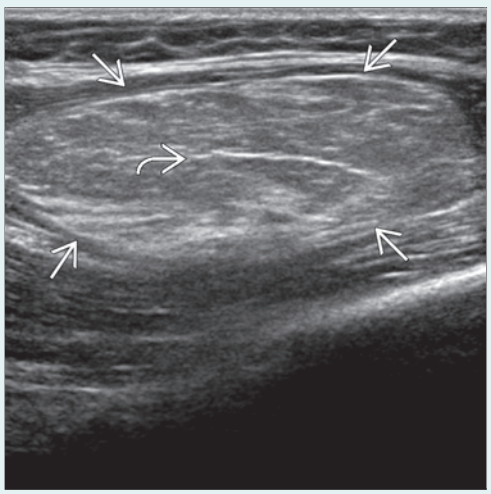
(Left) *Graphic shows a well-defined lipoma located in the subcutaneous tissue overlying the acromion.* ***(Right)*** *Longitudinal ultrasound shows an encapsulated subcutaneous mass hypoechoic to adjacent subcutaneous fat & fine internal echogenic striations parallel to the long axis of the mass. These appearances are characteristic of lipoma.*





(Left) *Longitudinal ultrasound shows a small well-defined homogeneously hyperechoic subcutaneous lipoma. The fine striations are barely perceivable though these appearances are still characteristic of a lipoma. Such lipomas are often multiple & tend to be located more centrally than peripherally.* ***(Right)*** *Longitudinal ultrasound shows an intramuscular hyperechoic lipoma within the vastus lateralis muscle. Note the well-defined hyperechoic capsule & the fine linear horizontal striations.*





LIPOMA

TERMINOLOGY

Abbreviations
- Fatty tumor
  - 9 distinct types of benign fatty tumor
    - Most common: Lipoma, angiolipoma, lipomatosis
    - Less common: Lipomatosis of nerve, lipoblastoma/lipoblastomatosis, spindle-cell lipoma/pleomorphic lipoma, hibernoma
    - Rare: Myolipoma of soft tissue, chondroid lipoma

Definitions
- Lipoma: Benign soft tissue tumor composed of mature adipose tissue
- Lipomatosis: Diffuse overgrowth of mature adipose tissue that infiltrates soft tissues of affected part; more common in children
- Angiolipoma: Lipoma in which small capillary-sized vessels containing microthrombi transverse the tumor
- Lipoblastoma/lipoblastomatosis: Admixture of mature & immature adipocytes; more common in children
- Myolipoma: Benign tumor exhibiting features of mature smooth muscles & mature adipose tissue
- Spindle cell lipoma/pleomorphic lipoma: Mixture of fat & spindle cells; more common in subcutaneous tissue and adult males
- Hibernoma: Tumor of brown (thermogenic) fat similar to that found in hibernating animals; more common in subcutaneous tissues, especially lower neck, mediastinum & upper dorsal region, & in adults

IMAGING

General Features
- Best diagnostic clue
  - Echogenic mass with fine internal echoes aligned parallel to long axis of tumor
- Location
  - Subcutaneous, most common
    - Posterior trunk, extremities, neck
    - Multifocal: 10%
  - Subfascial (deep to investing fascia)
    - Intramuscular, intermuscular, supramuscular (i.e., subfascial), & submuscular (i.e., juxtacortical) locations
  - Lipomas do not transverse investing fascia
- Size
  - < 5 cm: 80%; > 10 cm: Uncommon
- Morphology
  - Well-defined homogeneous fatty soft tissue mass

Radiographic Findings
- Radiography
  - Hypodense soft tissue mass ± calcification or ossification occasionally

CT Findings
- NECT
  - Well-defined, homogeneous soft tissue mass of low attenuation (-65 to -120 HU)

MR Findings
- T1WI
  - Well-defined mass with high signal intensity
  - Fine septa
  - MR is more reliable than ultrasound at depicting features suspicious for malignancy
    - Thick (> 2 mm) septations
    - Nodular or globular areas of nonfatty tissue
    - Well-differentiated liposarcoma usually composed of > 75% fatty component, while other histological subtypes composed of < 25% fatty component
- T2WI
  - Intermediate signal intensity
- STIR
  - Low signal intensity (fat signal suppressed)
- T1WI C+
  - Intravenous contrast is usually not required if no malignant features on noncontrast imaging
  - No enhancement or thin (< 2 mm) enhancing septa

Ultrasonographic Findings
- Well-defined, encapsulated mass, isoechoic to fat, hyperechoic to muscle
  - Variable echogenicity depending on cellularity & fat-water content
- Distinctive, fine linear striations parallel to skin
  - Striations may not be present in small lipomas
- Typically fusiform or oblong in shape
  - Some subcutaneous lipomas may be more uniform & rounded with less distinct striations
    - Particularly if multiple & located in trunk & proximal parts of appendicular skeleton
- Encapsulated
  - Helps differentiate lipoma from subcutaneous lipohypertrophy
  - Small rounded lesions may not have demonstrable capsule
- Acoustic enhancement is not a feature of superficial lipoma
- Compressible similar to adjacent fat
- May calcify or ossify
- Absent internal vascularity on color Doppler imaging
  - Consider angiolipoma if mild to moderate internal vascularity is present
  - Large lipoma may encase vessels & this feature should not be confused with angiolipoma
- Ultrasound findings are diagnostic in majority of cases
  - No need for histological confirmation or further imaging for nearly all superficial lipomas
- Subfascial lipomas are more variable in appearance
  - Still have fine striations parallel to long axis of tumor
  - Iso- or hyperechoic to adjacent muscle
  - Usually show acoustic enhancement (acoustic transmission of fat > muscle)
  - ± minimal to mild vascularity, more vascular than subcutaneous lipoma
  - Ultrasound can usually indicate diagnosis
    - ± MR to confirm lipomatous nature of mass & to exclude features of liposarcoma
    - MR is better at differentiating lipoma from liposarcoma than ultrasound
  - Large size, increasing size, deep location, & heterogeneity are best indicators of liposarcoma
    - However, not all heterogeneity within tumor necessarily implies liposarcoma
      - Calcification, small nonfatty areas, myxoid tissue, & fat necrosis can be features of atypical

LIPOMA

lipoma & are not necessarily diagnostic of liposarcoma
- No recognized characteristic ultrasound feature of hibernoma
  - Tends to occur most commonly in thigh & may show ↑ activity on FDG PET imaging

Imaging Recommendations
- Best imaging tool
  - Ultrasound
- Protocol advice
  - Avoid transducer pressure as lipoma is easily compressible
  - Look for encapsulation & fine horizontal striations within mass
  - Routinely evaluate with color Doppler imaging

DIFFERENTIAL DIAGNOSIS

Lipohypertrophy
- Localized ↑ in subcutaneous fat thickness
  - Nonencapsulated
  - Hypertrophied fat gradually merges with normal thickness surrounding fat
  - Similar to lipomatosis except that lipomatosis is more diffuse and ↑ in both superficial & deep fat

Fat Trauma
- Focal subcutaneous fat edema
  - Trauma may be trivial (& forgotten) & precede onset of mass by days to weeks
  - No discrete mass
  - Occurs at sites prone to trauma (gluteal region, thighs, & shins)

Vascular Malformation
- Often have large fatty stromal component & can be difficult to distinguish from lipoma, especially angiolipoma
  - Are not encapsulated & usually more poorly defined & less mass-like than angiolipomas
  - More vascular than angiolipomas and may show presence of phleboliths
  - Lipoma is generally more common in older age group than vascular malformation

PATHOLOGY

General Features
- Etiology
  - Mesenchymal neoplasm
  - More common in overweight subjects & diabetics
    - Clinical emergence of lipoma often coincides with period of weight gain
- Associated abnormalities
  - Familial multiple lipomas
    - Autosomal dominant inheritance
    - Multiple subcutaneous lipomas
    - ± hypercholesterolemia
- Lipoma fat is similar to normal body fat
  - Sheltered from systemic metabolism; therefore, lipoma does not change size with weight loss

Gross Pathologic & Surgical Features
- Soft, well-encapsulated, yellow lobulated mass
- Thin surrounding capsule
- Consists of yellow, normal-looking fat
- Greasy, myxoid cut surface

Microscopic Features
- Mature, uniform fat cells (adipocytes), slightly larger than nonneoplastic fat cells
- Fibrous connective tissue, associated with capsule or septations
- Well-vascularized with vessels compressed by distended adipocytes

CLINICAL ISSUES

Presentation
- Most common signs/symptoms
  - Compressible painless soft mass slowly growing over weeks to months
- Other signs/symptoms
  - May compress nerves if growing in confined space, e.g., carpal tunnel
  - Deep-seated tumors can have firm consistency & simulate sarcoma
    - Deep-seated tumors can become very large before becoming clinically apparent

Demographics
- Age
  - Peak: 40-60 years
- Epidemiology
  - Most common soft tissue tumor
    - Accounts for ~ 50% of all soft tissue tumors
  - 1% of population

Natural History & Prognosis
- Slow-growing mass that becomes latent over time

Treatment
- Excision of large, symptomatic, or suspicious lesions
  - Recurrence: 5%
- Liposuction or lipolysis

DIAGNOSTIC CHECKLIST

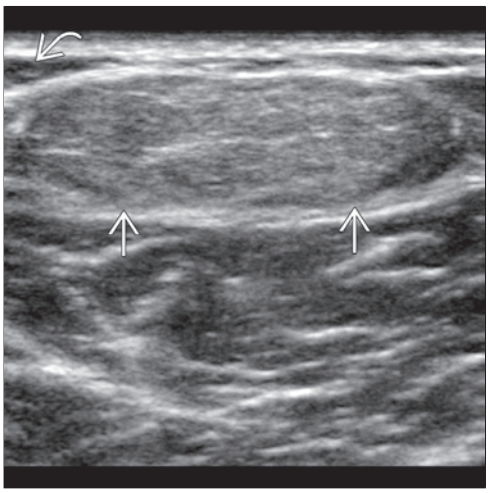
Consider
- Ultrasound findings are usually characteristic for superficial lipomas
- Ultrasound is useful for confirming diagnosis & for assessing extent & relationship with neurovascular bundle
- MR is better than ultrasound in differentiation of benign or malignant lipoma
- MR is useful for assessment of large, deep-seated lipoma
- Often not possible to distinguish deep-seated lipoma from well-differentiated liposarcoma on imaging or percutaneous biopsy

Image Interpretation Pearls
- Fine internal striations parallel to long axis of tumor = characteristic US finding

SELECTED REFERENCES

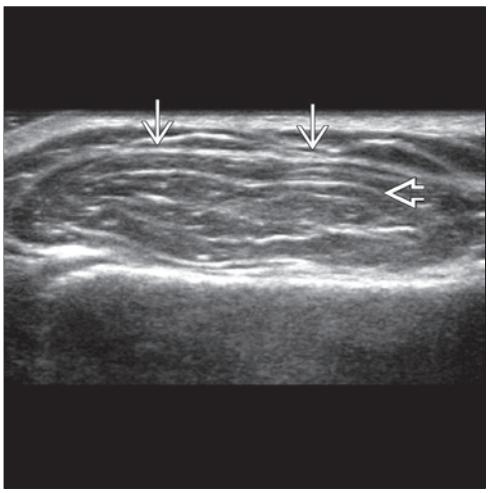
1. Paunipagar BK et al: Ultrasound features of deep-seated lipomas. Insights Imaging. 1(3):149-153, 2010

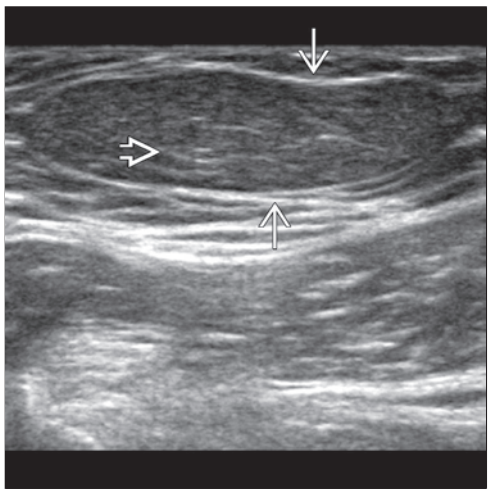
LIPOMA





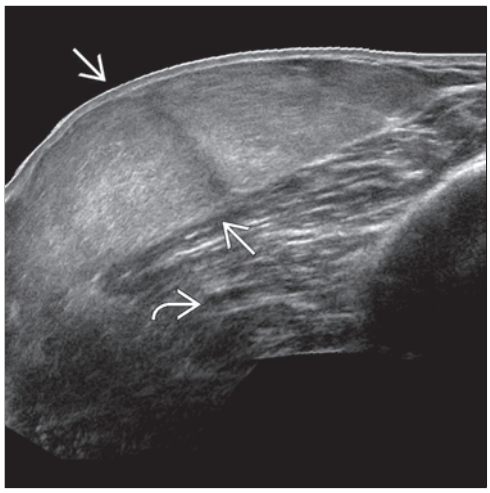
(Left) *Longitudinal ultrasound shows an oblong, encapsulated subcutaneous lipoma with fine linear internal striations parallel to the long axis of the tumor. The lipoma is hyperechoic to the surrounding subcutaneous fat.* ***(Right)*** *Transverse ultrasound shows an encapsulated subcutaneous lipoma with fine linear internal striations parallel to the long axis of the tumor. The lipoma is isoechoic to adjacent subcutaneous fat.*





(Left) *Longitudinal ultrasound shows a lobulated subcutaneous mass isoechoic to adjacent fat with distinct internal horizontal striations aligned parallel to the skin. These linear striations are slightly thicker than usual though the appearances are still entirely consistent with a subcutaneous lipoma.* ***(Right)*** *Longitudinal ultrasound shows a lobulated subcutaneous lipoma isoechoic to adjacent subcutaneous fat. Note the well-defined capsule and the fine internal striations.*

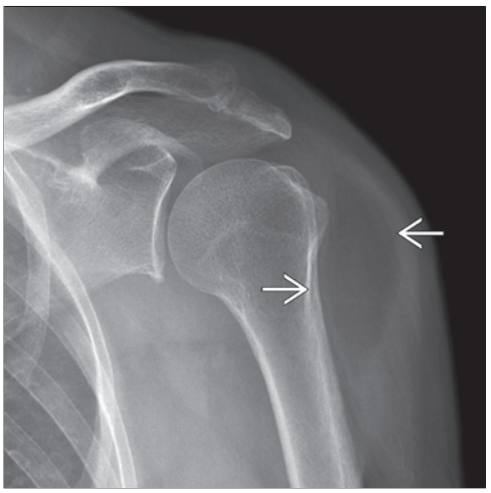


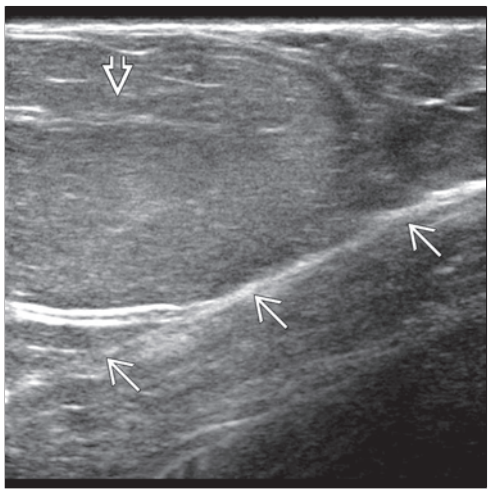


(Left) *Clinical photograph shows a large mass on the anterior aspect of the proximal arm.* ***(Right)*** *Longitudinal ultrasound with extended field-of-view of the same patient shows a large hyperechoic subcutaneous lipoma causing focal contour bulging of the skin. The underlying deltoid muscle is normal. Subcutaneous lipomas do not extend into the subfascial tissues and vice versa.*

LIPOMA

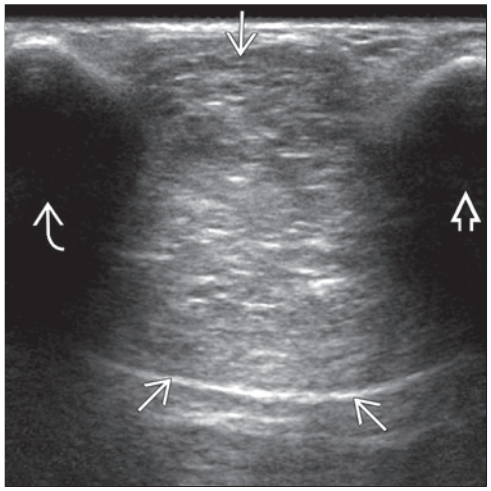
(Left) *Anteroposterior radiograph of the shoulder shows a well-defined radiolucent mass, suggestive of a lipoma, within the soft tissues lateral to the proximal humerus.* ***(Right)*** *Longitudinal ultrasound shows an encapsulated superficial lipoma abutting but not extending through the investing fascia.*



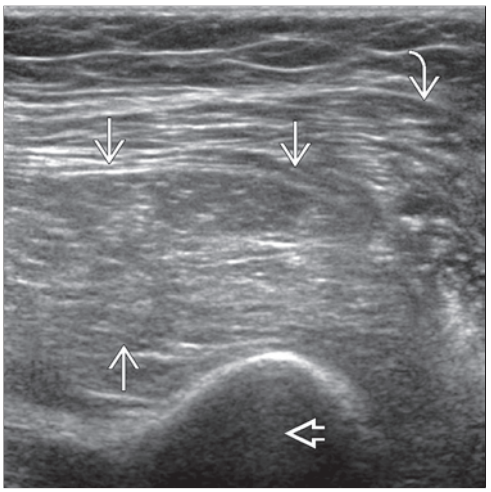


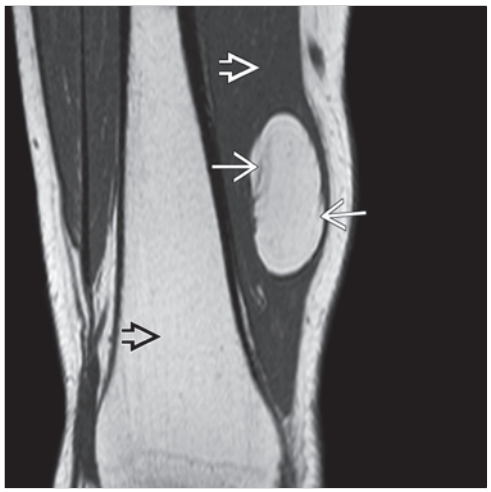
(Left) *Clinical photograph shows a mass in the 2nd web space between the index and middle fingers.* ***(Right)*** *Transverse ultrasound of the same patient shows a well-defined, dumbbell-shaped lipomatous mass in the web space between the 2nd and 3rd metacarpal bones. Note the fine linear striations parallel to the skin within the tumor, which are indicative of a lipoma.*



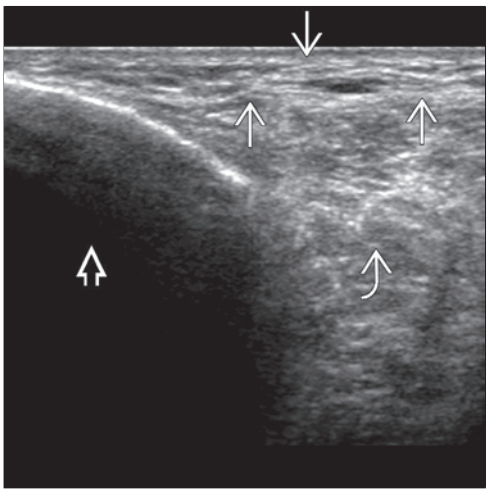


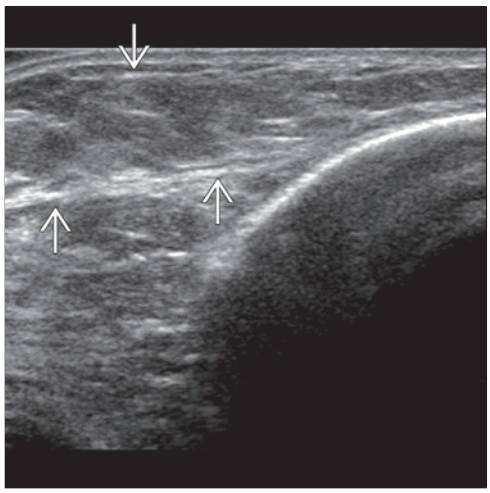
(Left) *Transverse ultrasound shows an intramuscular lipoma within the vastus medialis muscle close to the distal femur. The lipoma is isoechoic to muscle.* ***(Right)*** *Coronal T1WI MR of the same patient shows the well-defined lipoma within the vastus medialis muscle. Note the thin internal septations. The appearances are consistent with an intramuscular lipoma. The femur is normal.*



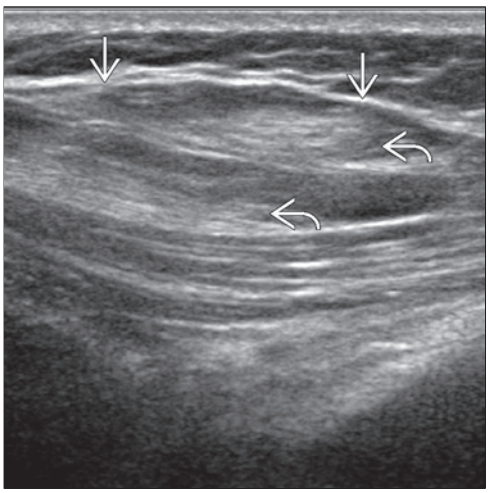


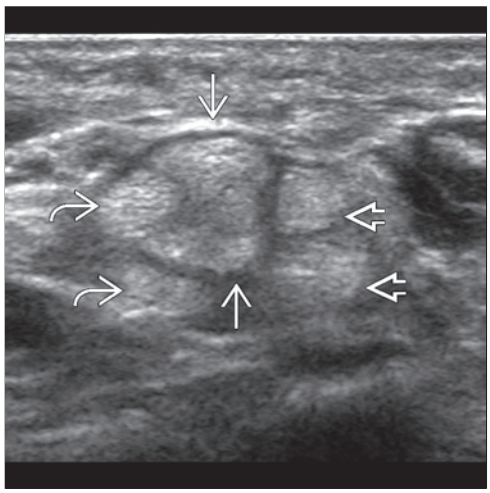
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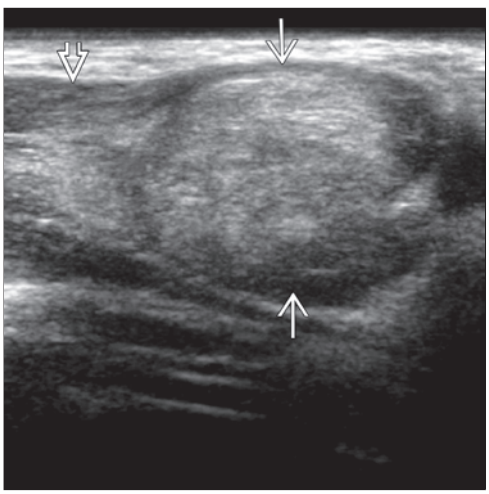


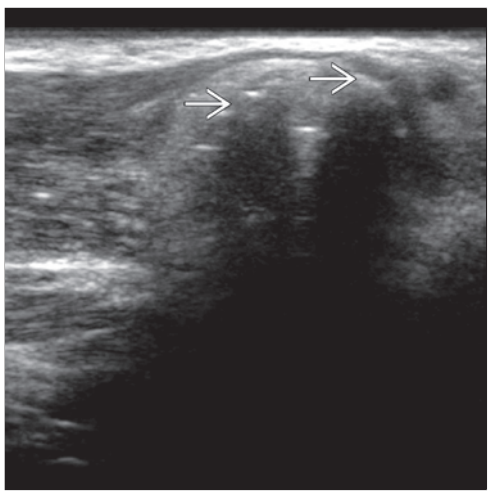
(Left) *Transverse ultrasound of the shin shows the normal appearance of the subcutaneous fat layer. Note the tibia and anterior tibialis muscle.* ***(Right)*** *Transverse ultrasound of the contralateral shin of the same patient shows moderate diffuse thickening of the subcutaneous fat without a discrete mass being present. This is consistent with localized subcutaneous lipohypertrophy. Comparison with the same area on the contralateral limb is very helpful in such cases.*





(Left) *Longitudinal ultrasound of the shoulder shows a poorly defined intramuscular lipoma confined within the myofascia of the deltoid muscle.* ***(Right)*** *Transverse ultrasound of the wrist shows a hyperechoic lipoma lying between the flexor tendons of the middle finger and the ring finger, and partially engulfing the superficial flexor tendon of the middle finger.*

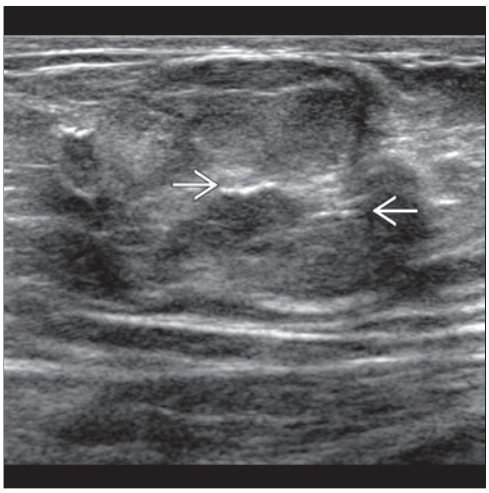




(Left) *Longitudinal ultrasound of the hand shows a hyperechoic lipomatous mass within the interosseous muscle between the thumb & index finger metacarpal bones. Note the fine linear striations consistent with an intramuscular lipoma.* ***(Right)*** *Longitudinal ultrasound of the same tumor shows multiple, small, calcific foci within the lipoma with posterior shadowing. The appearances are consistent with a calcified intramuscular lipoma.*

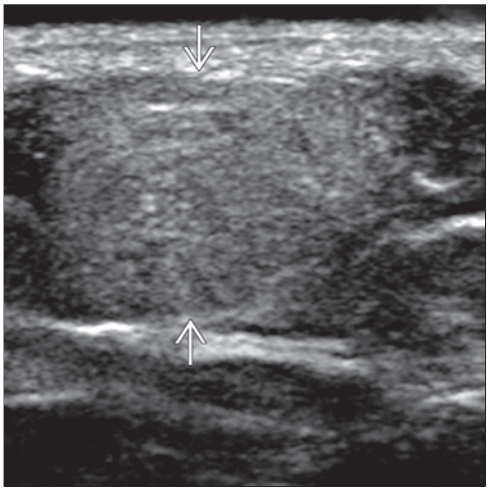
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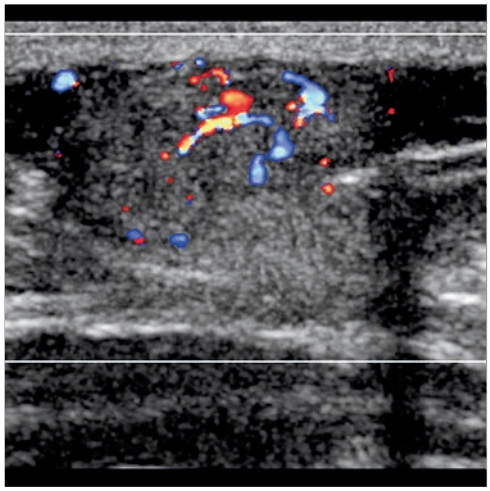
(Left) *Transverse ultrasound of the groin region shows a moderately heterogeneous subcutaneous lipomatous mass with linear echogenic foci. The differential diagnosis is atypical lipoma, fibrolipoma, or slow-flow vascular malformation.* ***(Right)*** *Transverse CT of the same lesion shows a lipomatous mass with a slightly thickened peripheral rim consistent with an atypical lipoma. Histology revealed a lipoma with central fat necrosis, calcification, and fibrinous stranding.*



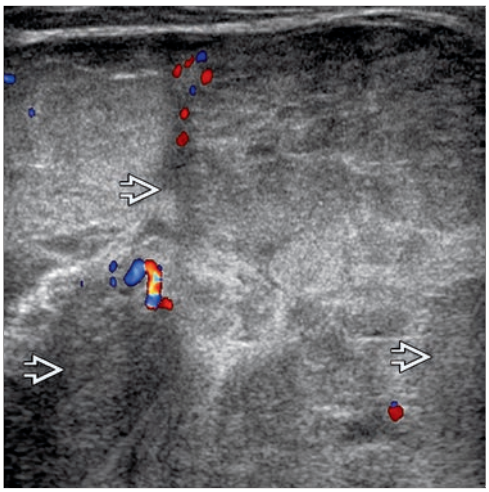


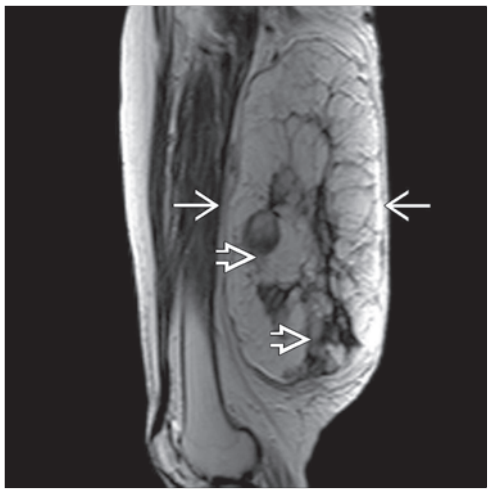
(Left) *Longitudinal ultrasound of the proximal thigh shows a quite well-defined hyperechoic subcutaneous mass.* ***(Right)*** *Longitudinal color Doppler ultrasound of the same lesion shows moderate intrinsic vascularity within the echogenic mass lesion, consistent with an angiolipoma. This was confirmed by pathology following excision.*



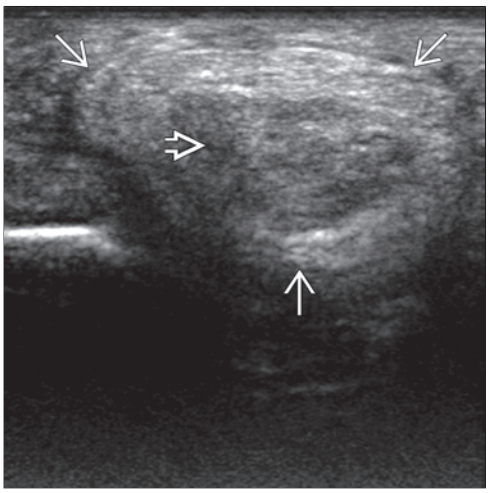


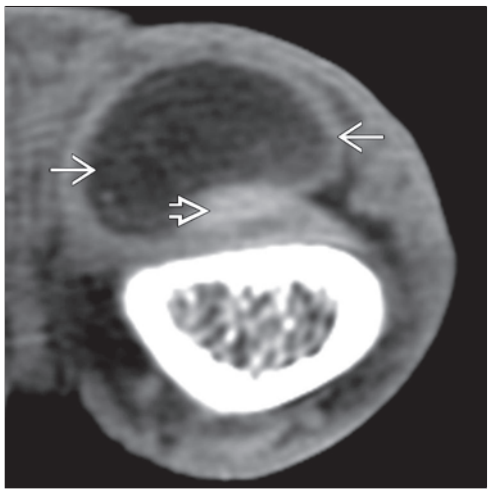
(Left) *Longitudinal ultrasound of a pathologically proven myxoid liposarcoma shows a large intramuscular heterogeneous lipomatous mass with moderate intrinsic vascularity and areas of non-lipomatous hypoechoic tissue.* ***(Right)*** *Longitudinal T1WI MR of the same lesion shows a large heterogeneous lipomatous mass in the posterior thigh with medium-sized areas of nonfatty tissue and thickened septa.*



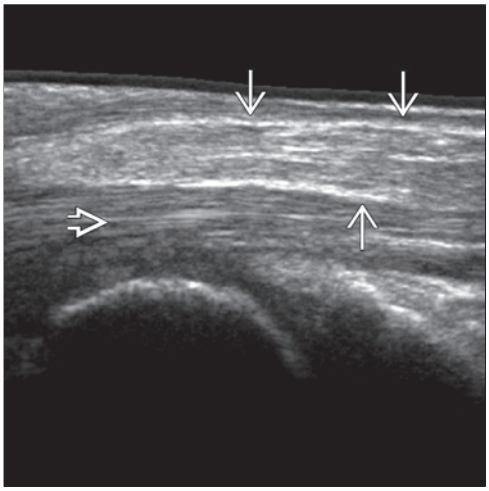


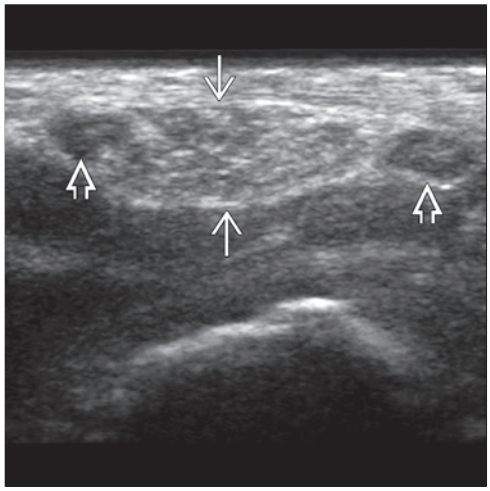
LIPOMA



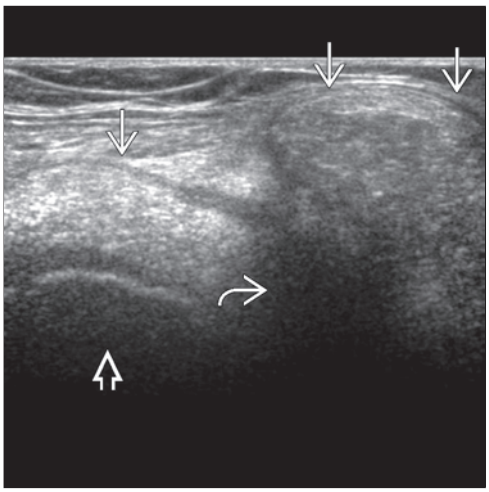


(Left) *Ultrasound of a pathologically proven lipoma on the plantar aspect of the big toe shows a well-defined hyperechoic lipomatous mass* ➔ *with a hypoechoic central area* ➔. ***(Right)*** *Transverse computed tomography of the same lesion show a homogeneously fatty mass* ➔ *located just superficial to the flexor hallucis tendon* ➔.





(Left) *Longitudinal ultrasound of the wrist shows a lipoma* ➔ *located superficial to the flexor tendons. Note the fibrillar echotexture of the flexor tendons* ➔. ***(Right)*** *Transverse ultrasound of the same lesion shows that the lipoma* ➔ *is located between and separating both components* ➔ *of a bifid median nerve.*





(Left) *Longitudinal ultrasound shows a lipomatous-type mass* ➔ *at the the posterior aspect of the knee joint. The large size of the mass and the associated acoustic shadowing hinders full assessment of deep or intraarticular involvement* ➔. *Note the femoral condyle* ➔. ***(Right)*** *Longitudinal T1WI MR of the same lesion shows the mass to be an intraarticular lipoma* ➔ *bulging into the posterior joint capsule. The full extent of this large lipoma is best appreciated on MR imaging.*

EPIDERMOID CYST

Key Facts

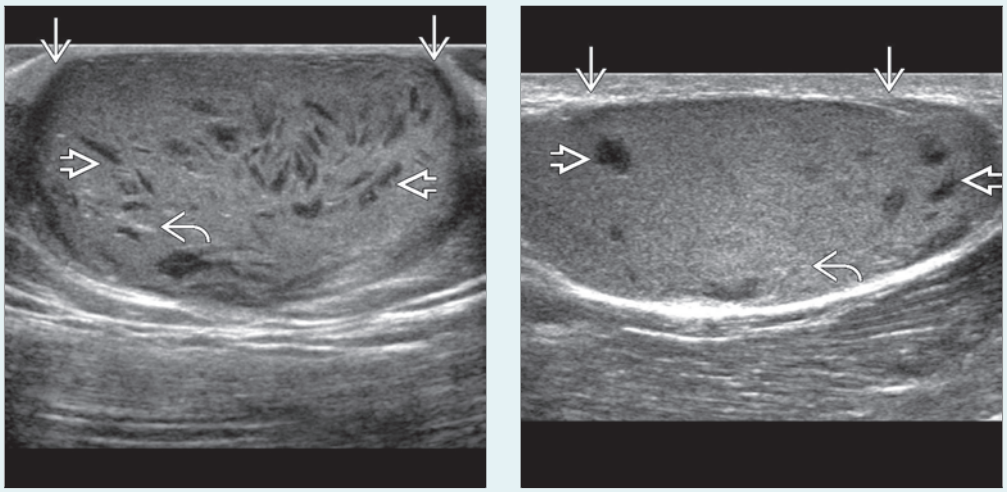
Terminology
- Slow-growing subdermal cyst that contains keratin and is lined by stratified squamous epithelium
  - Cyst wall must not contain dermal elements

Imaging
- Ultrasound appearances depend on maturation of cyst and amount and compactness of keratin
  - ± presence of cyst rupture and degree of cyst collapse
- Well-circumscribed ovoid (80%), lobulated (19%), or tubular (1%) configuration
- Increased acoustic transmission (96%)
- Most are heterogeneous and mildly hyperechoic
- Some homogeneous with pseudotestis appearance
- Linear hyperreflective disc-like areas represent layered keratin aggregates ± cholesterol deposition
- Cleft-like or filiform anechoic or hypoechoic areas are due to cyst-like spaces lacking keratin
- Thin hypoechoic cyst wall
  - Hypoechoic tract extending from superficial wall to dermis (10%) (punctum)
- Contained rupture → lobulated configuration of cyst
- Most epidermoid cysts are avascular
  - Peripheral and pericystic vascularity is feature of cyst rupture and inflammation
- Sensitivity/specificity of ultrasound in making diagnosis of epidermoid cyst is 80% and 95%, respectively

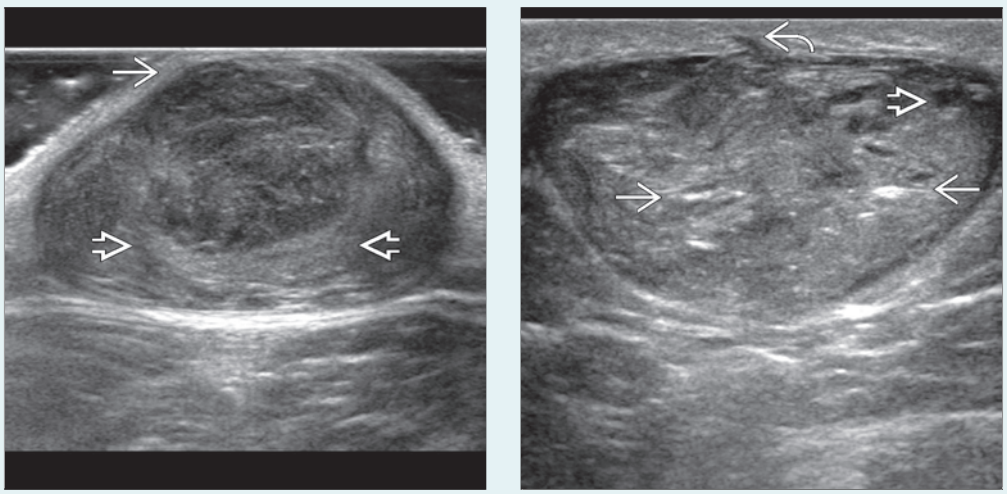
Top Differential Diagnoses
- Nerve sheath tumor, soft tissue abscess, lipoma

Diagnostic Checklist
- Consider localized leakage of cyst content if inflammation is present around epidermoid cyst

(Left) *Longitudinal ultrasound shows a well-circumscribed hypoechoic epidermoid cyst with dermal attachment, multiple internal filiform anechoic areas, linear hyperreflective strands, and posterior acoustic enhancement.* ***(Right)*** *Longitudinal ultrasound shows a well-circumscribed mildly echogenic epidermoid cyst with dermal attachment. The cyst is quite homogeneous with scattered internal hypoechoic areas. Note the faint echogenic hyperreflective foci.*



(Left) *Longitudinal ultrasound shows a well-circumscribed epidermoid cyst with dermal attachment, heterogeneous echogenic content, alternate layering, multiple floating echogenic foci, and increased through transmission.* ***(Right)*** *Longitudinal ultrasound shows typical appearances with a well-circumscribed ovoid heterogeneous nodule with dermal attachment, internal floating hyperreflective strands, small hypoechoic areas, and a hypoechoic tract extending to a cutaneous punctum.*



EPIDERMOID CYST

TERMINOLOGY

Synonyms
- Epidermal inclusion cyst, epidermal cyst, infundibular cyst, sebaceous cyst

Definitions
- Slow-growing subdermal cyst that contains keratin and is lined by stratified squamous epithelium
  - Some cysts are due to ductal blockage of hair follicles with downward growth of epithelial cells
  - Some cysts are due to traumatic or embryological subdermal sequestration of epithelial tissue
    - Histologically similar and hence grouped under general term "epidermoid cyst"
  - Wall of cyst must not contain dermal elements
    - Presence of dermal elements → designation as dermoid cyst
  - Epidermis = outer layers of skin
    - Contains specialized cells such as keratinocytes, corneocytes, and melanocytes
  - Dermis = inner layers of skin that support the epidermis
    - Contains hair follicles, nerves, sweat glands, small blood vessels, and sebaceous glands

IMAGING

General Features
- Best diagnostic clue
  - Well-circumscribed cyst-like mass with thick, linear, seed-like hyperechoic foci, filiform anechoic areas, and dermal attachment
- Location
  - Predominately in those areas with most body hair
  - Most commonly seen in head and neck
  - Trunk and extremities less commonly found
    - Most cysts occurring in relatively hairless areas such as the palm or sole are implantation epidermoid cysts
    - Trauma → implantation of epidermal elements to dermis or subcutis, which then survive, grow, and produce keratin
  - Can occur within tendon or within bone
- Size
  - < 1 cm to > 10 cm, usually < 5 cm
- Morphology
  - Well-circumscribed subcutaneous or dermal mass

Radiographic Findings
- Soft tissue swelling if large size
- Rarely bony remodeling or lytic bone lesion with sclerotic border

CT Findings
- Noncalcified soft tissue attenuation mass in subdermal layer
  - Low-density, fluid-like attenuation due to high lipid content
    - Rarely hyperdense due to hemorrhage, saponification, or high protein content
- No enhancement or minimal rim enhancement

MR Findings
- T1WI
  - Isointense to slightly hyperintense relative to muscle
- T2WI
  - Hyperintense signal with high or low signal intensity content
    - Low-signal debris represents keratin aggregates
    - High-signal debris represents cholesterol deposition
  - Content may be positionally dependent or layered concentrically
  - Fluid-fluid levels may occur
  - T2-hypointense rim due to stratified squamous epithelial wall
- T1WI C+
  - Absent to low level of central enhancement with enhancing capsule

Ultrasonographic Findings
- Ultrasound appearances depend on maturation of cyst, compactness, and amount of keratin
  - ± presence of cyst rupture and degree of cyst collapse
- Well-circumscribed ovoid (80%), lobulated (19%), or tubular (1%) configuration
- Dermal attachment (i.e., no intervening subcutaneous fat between lesion and dermis)
  - ± dermal protrusion
  - ± cutaneous punctum
    - Feature of blocked duct etiology
    - May not be present if implantation etiology
- Hypoechoic punctum seen between cyst and dermis in 10% of those referred for ultrasound examination
  - Many of those with clinically obvious punctum may not be referred for ultrasound
- Cyst confined to subcutaneous tissue
  - No subfascial extension
- Most are unilocular
- Most cysts are heterogeneous and mildly hyperechoic
- Some cysts are homogeneous with pseudotestis appearance
  - Linear hyperreflective disc-like areas represent layered keratin aggregates ± cholesterol deposition
  - Cleft-like or filiform anechoic or hypoechoic areas are due to cyst-like spaces lacking keratin
  - ± multi-layered appearance with hyperechoic and hypoechoic rings
  - ± target appearance with hyperechoic center surrounded by hypoechoic rim
  - ± "swirling" of mobile cyst contents when compressed
- Increased acoustic transmission (96%)
- Thin hypoechoic cyst wall
  - Focal discontinuity indicative of cyst rupture
- Irregular cyst contour indicative of cyst rupture
  - Localized contained rupture may give rise to lobulated configuration
- Most epidermoid cysts are avascular
  - Peripheral vascularity, or occasionally central vascularity, is feature of previously ruptured cysts
  - Leakage of cyst contents → pericystic inflammation
- Sensitivity/specificity of ultrasound in making diagnosis of epidermoid cyst is 80% and 95%, respectively
  - Most cysts have distinctive ultrasound appearance

EPIDERMOID CYST

Imaging Recommendations
- Best imaging tool
  - Ultrasound
    - Can make a correct diagnosis in majority of cases
- Protocol advice
  - Transverse, longitudinal scan, and color Doppler imaging
    - Determine any connection with dermis
    - Ensure continuity of cyst wall
    - Determine any rupture ± surrounding inflammation

DIFFERENTIAL DIAGNOSIS

Nerve Sheath Tumor
- Occurs along neurovascular bundle
- Usually hypervascular and hypoechoic
- Thickening of entering and exiting nerves

Glomus Tumor
- Hypervascular
- Homogeneous, usually hypoechoic

Soft Tissue Abscess
- Can be difficult to differentiate from infected or ruptured epidermoid cyst
- Liquefied component of abscess

Lipoma
- Isoechoic to adjacent subcutaneous fat
- Fixed linear fine horizontal echogenic striations parallel to skin
- More homogeneous than epidermoid cysts

Pilomatricoma
- Usually calcified
- Moderately vascular
- Peripheral hypoechoic rim

PATHOLOGY

General Features
- Etiology
  - Downward growth of epidermal cells following obstruction of pilosebaceous unit (composed of hair follicle, sebaceous gland, and arrector pili muscle)
  - Downward rupture of obstructed pilosebaceous unit
  - Embryological sequestration of epidermal tissue into subdermal tissues
  - Traumatic sequestration of epidermal tissue into subdermal tissues

Gross Pathologic & Surgical Features
- Elastic mass with "butter and cheese" content
- Microscopic features
  - Simple cyst with walls of stratified squamous epithelium
    - Walls do not contain dermal elements such as sebaceous glands or hair follicles
  - Lumen filled with laminated keratinaceous material
- Additional findings associated with cyst rupture
  - Pericystic granulomatous reaction with inflammation and fibrosis
  - Cyst contents excite foreign body reaction

CLINICAL ISSUES

Presentation
- Most common signs/symptoms
  - Most are incidental finding
- Other signs/symptoms
  - May report history of penetrating trauma many months or years earlier
  - Firm, slowly growing, painless mass
  - Mobile or tethered to skin
  - ± punctum
  - ± symptoms and sign of inflammation

Demographics
- Age
  - Any age; more common in 3rd to 5th decades
- Gender
  - M > F (slightly)
- Epidemiology
  - 7% of superficial masses referred for ultrasound
  - 12% of superficial masses surgically excised

Natural History & Prognosis
- May rupture, become inflamed or infected
  - Questionable as to how frequently epidermoid cysts become infected
  - No difference in microbiological milieu of infected and noninfected cysts
  - Most cyst "infections" probably due to inflammation induced by cyst rupture rather than true infection
- No local recurrence if complete surgical excision

Treatment
- Anti-inflammatory agents if cyst inflamed
- Antimicrobial agents if cyst infected
- Incision and expression of cyst contents
  - High rate of recurrence
- Incision and expression of cyst contents and removal of cyst wall through same minimal incision
- Total excision of cyst
- Laser therapy for cysts on face and other sensitive areas
- Surgery for previously ruptured epidermoid cysts associated with pericystic scarring is more complicated than surgery for nonruptured cysts

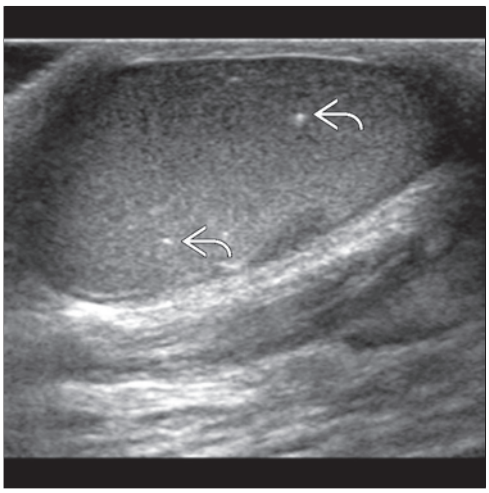
DIAGNOSTIC CHECKLIST

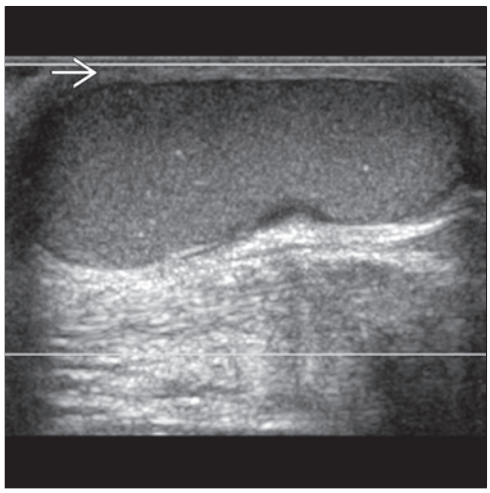
Consider
- Consider localized leakage of cyst content if inflammation present around the epidermoid cyst

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1. Yuan WH et al: Differences in sonographic features of ruptured and unruptured epidermal cysts. J Ultrasound Med. 31(2):265-72, 2012
2. Huang CC et al: Epidermal cysts in the superficial soft tissue: sonographic features with an emphasis on the pseudotestis pattern. J Ultrasound Med. 30(1):11-7, 2011
3. Kim HK et al: Subcutaneous epidermal inclusion cysts: ultrasound (US) and MR imaging findings. Skeletal Radiol. 40(11):1415-9, 2011

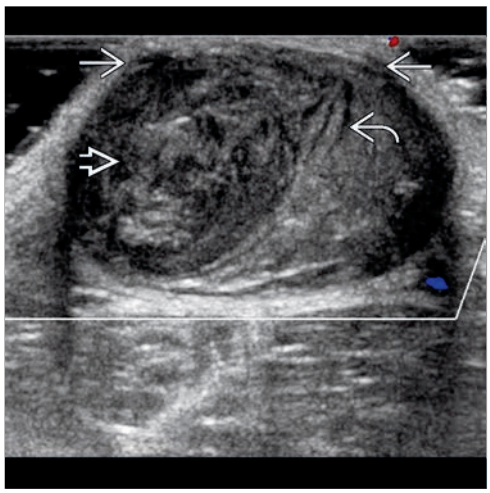
EPIDERMOID CYST



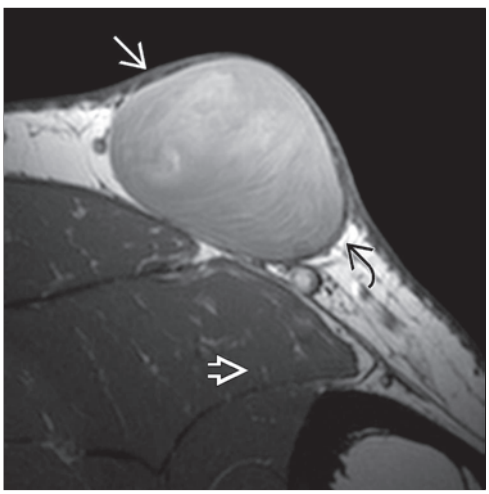


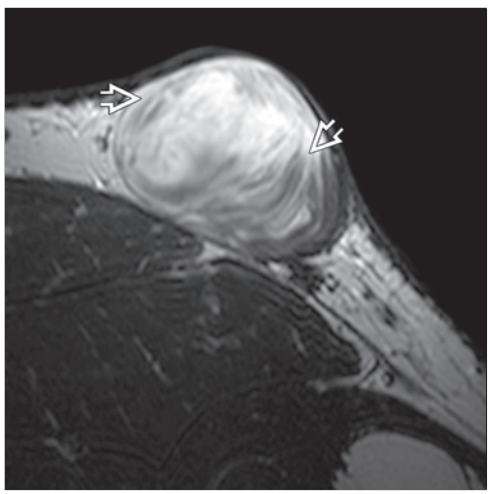
(Left) *Transverse ultrasound shows a well-circumscribed mildly echogenic epidermoid cyst with increased through transmission. The echotexture is homogeneous with a pseudotestis appearance. Note the echogenic foci due to either keratin or cholesterol aggregates.* ***(Right)*** *Longitudinal color Doppler ultrasound of the same lesion reveals no central or peripheral vascularity. Note there is no intervening fat between the epidermoid cyst and the dermis, which indicates dermal attachment.*





(Left) *Clinical photo shows a protuberant bluish nodule on the medial calf region. No obvious punctum is evident clinically.* ***(Right)*** *Transverse color Doppler ultrasound of the same lesion shows an ovoid heterogeneous epidermoid cyst with dermal attachment and protrusion. Internal filiform hypoechoic areas and a laminated pattern representing compacted keratin layers are shown. There is no intralesional vascularity. Note the mild posterior acoustic enhancement.*

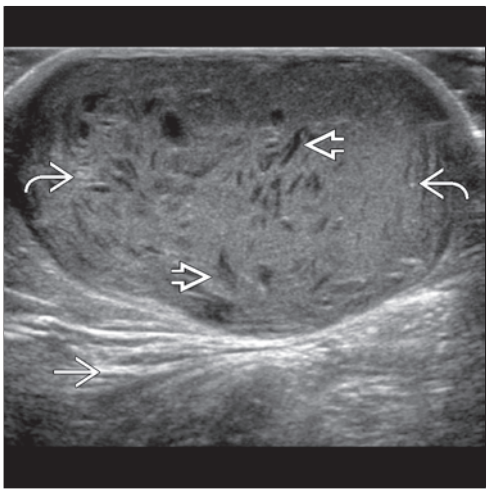


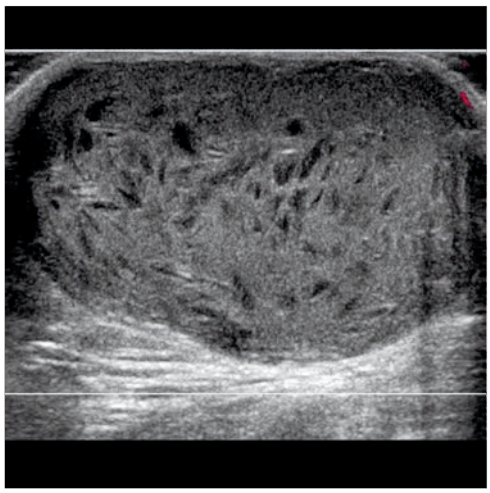


(Left) *Axial T1WI MR of the same well-defined, nonruptured epidermoid cyst shows attachment to the dermis. The content is mildly heterogeneous and moderately hyperintense to muscle. Note the thin yet distinct hypointense wall.* ***(Right)*** *Axial T2WI MR of the same lesion shows how the cyst content has cyst-like hyperintensity with hypointense lamina due to layers of compacted keratin. These features are very typical of an epidermoid cyst.*

EPIDERMOID CYST

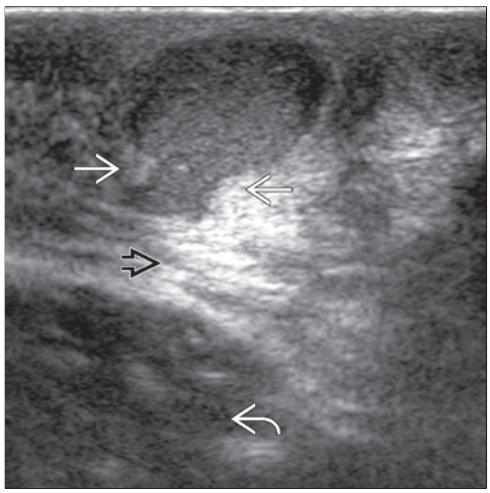
(Left) *Transverse ultrasound shows a well-circumscribed epidermoid cyst with increased through transmission, internal cleft-like hypoechoic areas, echogenic strands, and foci due to keratin and cholesterol aggregates.* ***(Right)*** *Transverse color Doppler ultrasound of the same cyst shows absence of central or marginal vascularity, which is a typical finding in epidermoid cyst without inflammation or rupture.*



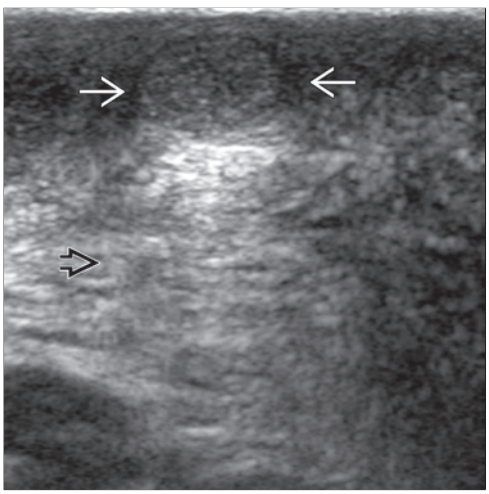


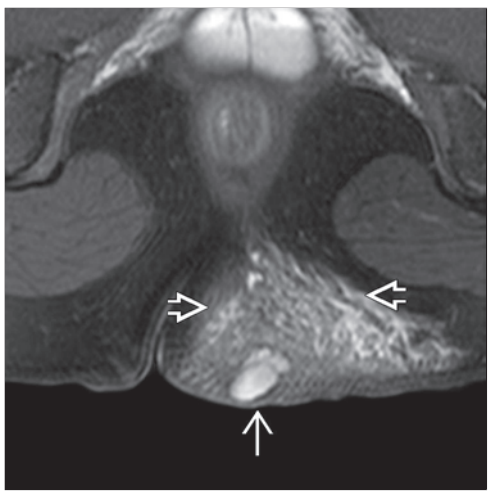
(Left) *Clinical photo shows 2 closely related superficial nodules associated with localized cutaneous erythema in the natal cleft region. Note the single small whitish spot due to a punctum.* ***(Right)*** *Transverse ultrasound of the same lesion shows a lobulated cystic subcutaneous nodule with slightly echogenic content and markedly increased through transmission. The irregular border of the epidermoid cyst is a sequelae of recent cyst rupture. Note the gluteal muscle.*



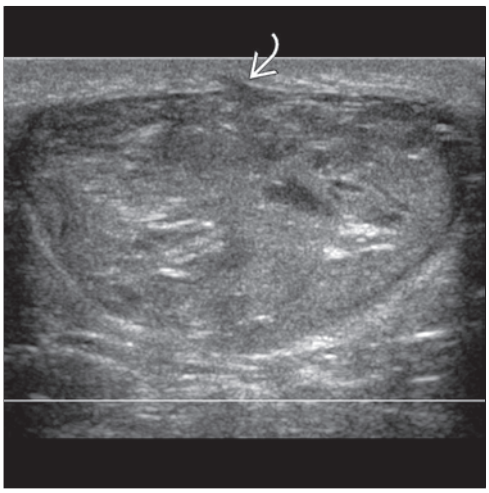


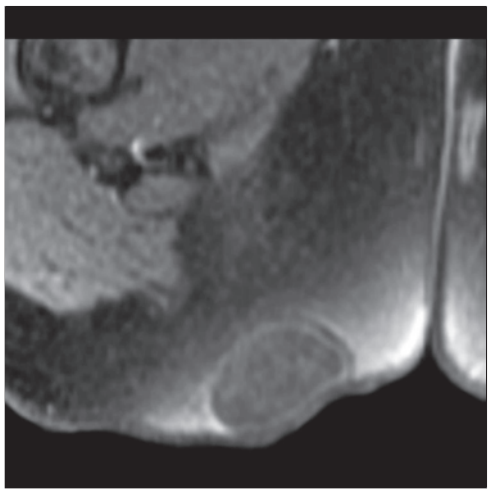
(Left) *Transverse ultrasound of the same patient shows a smaller nonruptured epidermoid cyst with a smooth, well-circumscribed border and prominent acoustic enhancement in close vicinity to the lobulated lesion.* ***(Right)*** *Axial T2WI FS MR of the same patient shows a hyperintense lesion with lobulated contour, hypointense rim, and moderate subcutaneous soft tissue edema, which is consistent with epidermoid cyst rupture.*



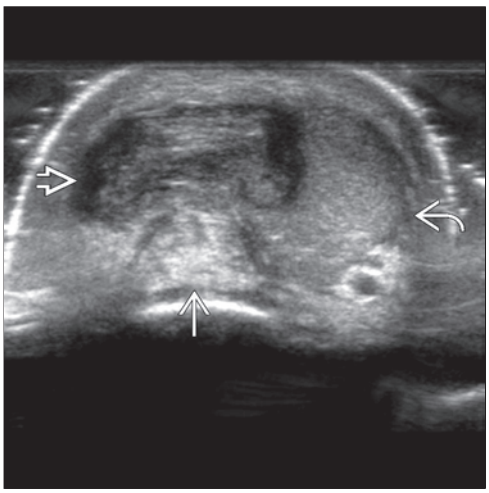


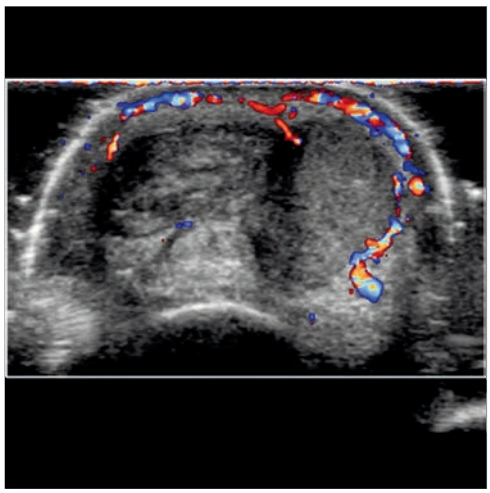
EPIDERMOID CYST



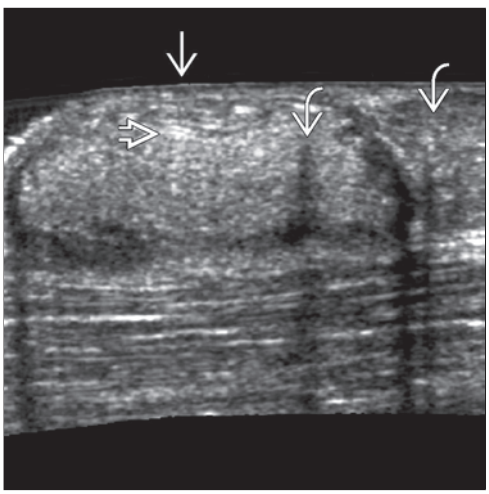


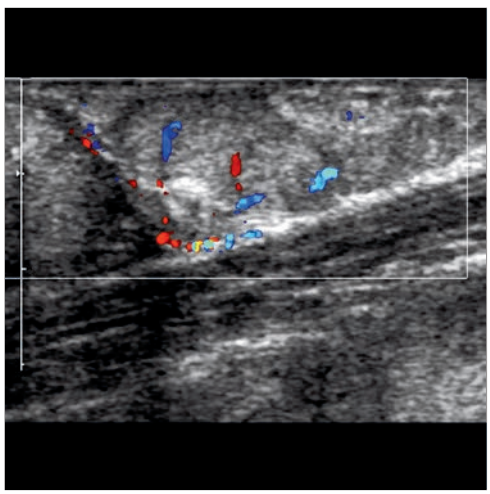
(Left) *Transverse color Doppler ultrasound shows a well-circumscribed epidermoid cyst with typical sonographic appearances and a linear hypoechoic tract extending to the dermis. Note the absence of vascularity in this uncomplicated cyst.* ***(Right)*** *Axial T1 C+ MR of the same lesion shows minimal enhancement of the cyst wall with a central nonenhancing component. There is no cyst rupture or pericystic inflammation.*





(Left) *Transverse ultrasound of a middle finger shows a bilobulated epidermoid cyst superficial to the flexor tendons . The lesion has both a homogeneous echogenic component and a layered heterogeneous component . Moderate pericystic edema is present. The ultrasound features of epidermoid cyst are determined by its internal content.* ***(Right)*** *Transverse color Doppler ultrasound of the same lesion shows moderate pericystic soft tissue hyperemia representing inflammation secondary to leakage of cyst contents.*





(Left) *Extended field-of-view ultrasound shows a lobulated hyperechoic nodule containing hyperreflective foci . Some of these hyperechoic foci are associated with posterior shadowing suggestive of calcific foci .* ***(Right)*** *Longitudinal color Doppler ultrasound of the same lesion shows mild central and peripheral vascularity. The lesion was proven pathologically to be a ruptured epidermoid cyst associated with granulomatous foreign body giant cell reaction.*

PILOMATRICOMA

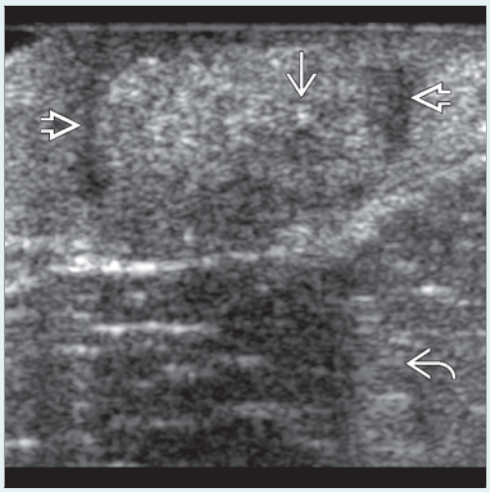
Key Facts

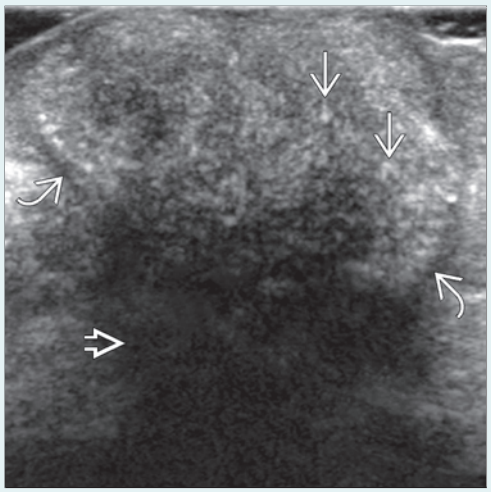
Terminology
- Synonym: Calcifying epithelioma of Malherbe
- Definition: Benign skin tumor arising from cells of hair matrix

Imaging
- Head & neck most common (58%), followed by upper extremities (23%), trunk (14%), and lower extremities (5%)
- Well-circumscribed ovoid heterogeneous solid subdermal mass containing matrix calcification, intrinsic vascularity, and peripheral hypoechoic rim
- Mass extending from dermal to subcutaneous tissues
- Ovoid (80%), round (11%), or irregular (9%)
- Hypoechoic (68%), isoechoic (16%), or hyperechoic (2%) to subcutaneous fat
- Internal hyperechoic foci due to matrix calcification (93%)
- Hypoechoic peripheral rim due to connective tissue capsule (65%)
- Intrinsic vascularity (50%)
- Capsular rupture can be associated with peritumoral inflammation
- Ultrasound appearances are sufficiently specific to make diagnosis in majority of cases

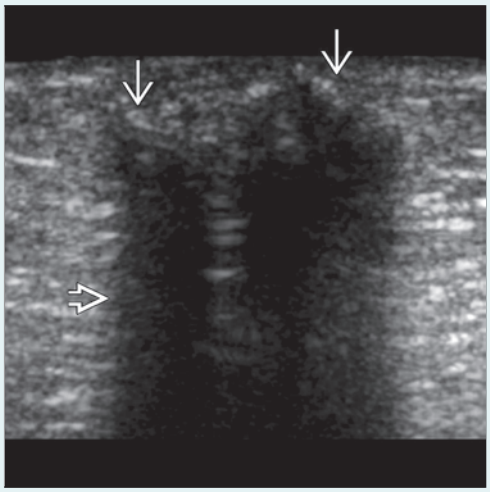
Top Differential Diagnoses
- Epidermoid cyst
- Hemangioma

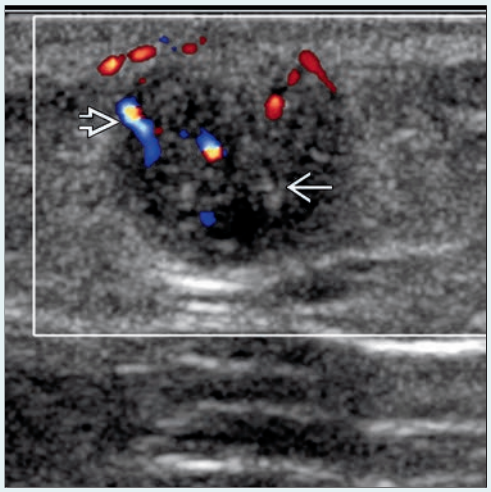
Clinical Issues
- Most present in children but can present at any age
  - 2nd most commonly excised superficial tumor after epidermoid cyst in children
- Treatment is surgical excision





(Left) *Transverse ultrasound shows a well-defined heterogeneous pilomatricoma in the subcutaneous layer. There are multiple scattered echogenic foci with mild posterior shadowing due to matrix calcification. Note the peripheral hypoechoic rim. The muscle layer is shown.* ***(Right)*** *Transverse ultrasound shows a heterogeneous pilomatricoma with dermal attachment, multiple scattered echogenic foci, and dense posterior shadowing. Note the well-defined hypoechoic peripheral rim.*





(Left) *Longitudinal ultrasound shows a subcutaneous pilomatricoma with multiple lumpy dense calcifications casting strong posterior shadowing, and limiting assessment of deeper margin.* ***(Right)*** *Transverse ultrasound shows a well-defined subcutaneous hypoechoic pilomatricoma with central & peripheral vascularity containing scattered small calcific foci.*

PILOMATRICOMA

TERMINOLOGY

Synonyms
- Calcifying epithelioma of Malherbe
- Pilomatrixoma

Definitions
- Benign skin tumor arising from cells of hair matrix

IMAGING

General Features
- Best diagnostic clue
  - Well-circumscribed subdermal mass lesion with heterogeneous echotexture, internal calcification, vascularity, and peripheral hypoechoic rim
- Location
  - Head & neck (58%), upper extremities (23%), trunk (14%), lower extremities (5%)
- Size
  - < 1 cm to 5 cm; mean diameter: 1.4 cm
- Morphology
  - Well-circumscribed, partially calcified mass lying between dermis and subcutaneous tissues

Radiographic Findings
- Visibility dependent on degree of tumoral calcification

CT Findings
- Nonspecific soft tissue attenuation mass in subcutaneous tissue ± calcification ± mild to moderate enhancement

MR Findings
- T1WI intermediate to low, T2WI hyperintense
- Calcification → low-signal foci
- Mild to moderate contrast enhancement

Ultrasonographic Findings
- Well-circumscribed mass extending from dermis to subcutaneous tissues
- Ovoid (80%), round (11%), or irregular (9%) in shape
- Hypoechoic (68%), isoechoic (16%), or hyperechoic (2%) to subcutaneous fat, heterogeneous (14%)
- Internal hyperechoic foci due to calcification in stroma or shadow cells (93%)
  - Scattered dots (most common), lump- or arc-like calcific deposits
- Hypoechoic peripheral rim due to connective tissue capsule (65%)
- Intrinsic vascularity (50%)
  - Peripheral, central, or combined peripheral and central
- ± posterior shadowing
  - Presence and amount of posterior shadowing depends on degree of matrix calcification
- ± surrounding inflammation
  - Inflammation due to capsular rupture

Imaging Recommendations
- Best imaging tool
  - Ultrasound
- Protocol advice
  - Assess shape, echotexture, internal calcification, hypoechoic rim, margin, posterior shadowing, and vascularity

DIFFERENTIAL DIAGNOSIS

Epidermoid Cyst
- Linear seed-like internal echogenic strands ± posterior enhancement
- No intrinsic vascularity unless ruptured

Hemangioma
- Fatty stroma with vascular channels ± phleboliths

PATHOLOGY

General Features
- Etiology
  - Usually sporadic, not familial
- Genetics
  - 75% have mutations in *CTNNB1* gene
    - Regulates β-catenin/LEF, which influences hair matrix cell tumorigenesis

Gross Pathologic & Surgical Features
- Basaloid proliferation of hair matrix cells
- These mature into structureless anucleate eosinophilic cells called shadow cells representing differentiation toward hair cortex
- Calcification occurs in shadow cells or stroma
- ± histiocytic multinucleate infiltrate at site of rupture

CLINICAL ISSUES

Presentation
- Most common signs/symptoms
  - Slow-growing hard subcutaneous mass ± localized inflammation ± skin discoloration
- Other signs/symptoms
  - Usually solitary, though multiple in up to 10%

Demographics
- Age
  - Particularly prevalent in children, typically first 2 years of life, though can present at any age
- Gender
  - Slight female predominance
- Epidemiology
  - 2nd most commonly excised superficial lump after epidermoid cyst in children

Natural History & Prognosis
- Spontaneous regression does not occur

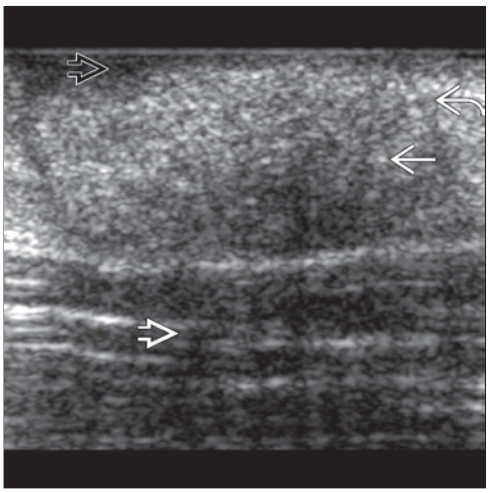
Treatment
- Complete surgical excision: Cure
  - Incomplete surgical excision: May recur

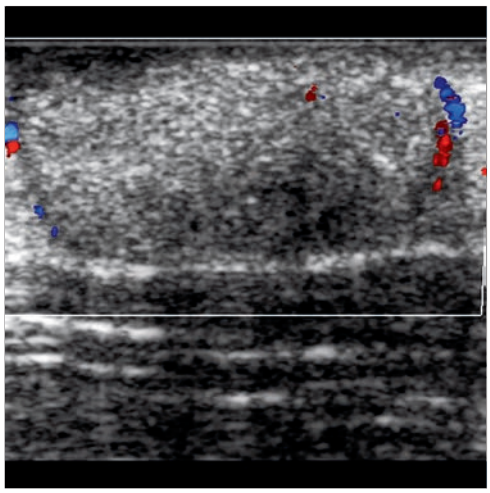
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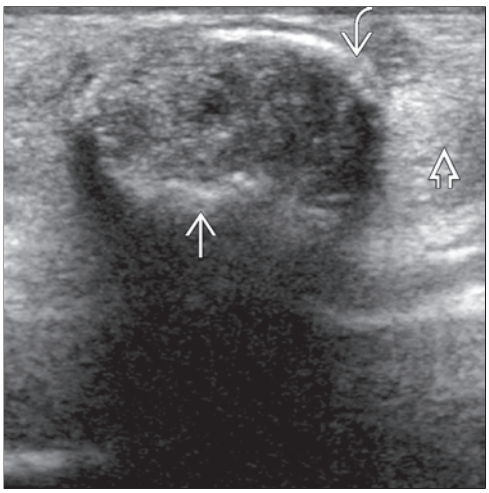
PILOMATRICOMA

(Left) *Longitudinal ultrasound of a young male shows a well-defined ovoid pilomatricoma with multiple small echogenic foci, mild posterior shadowing, and a hypoechoic peripheral rim due to the connective tissue capsule. The lesion is in contact superficially with the dermis.* ***(Right)*** *Longitudinal color Doppler ultrasound of the same lesion shows the presence of mild, predominantly peripheral vascularity.*



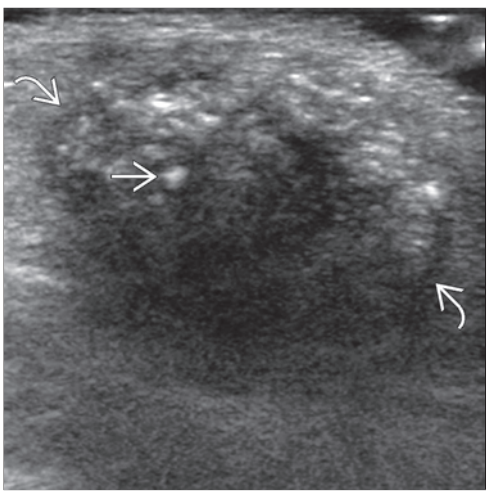


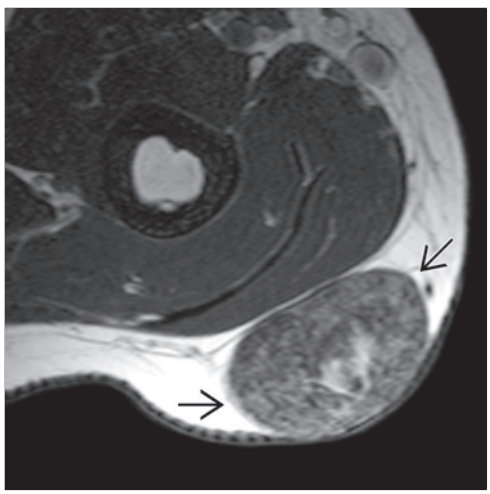
(Left) *Transverse ultrasound of a 13-year-old male shows a well-defined ovoid subcutaneous pilomatricoma. The mass is hypoechoic to adjacent subcutaneous fat and contains areas of both arc- & lump-like calcifications. Dense posterior acoustic shadowing is present.* ***(Right)*** *Lateral radiograph of the arm of a 10-year-old female shows a calcified mass due to a pilomatrixoma located posterior to the humerus. Radiography is helpful in densely calcified masses with severe acoustic shadowing.*



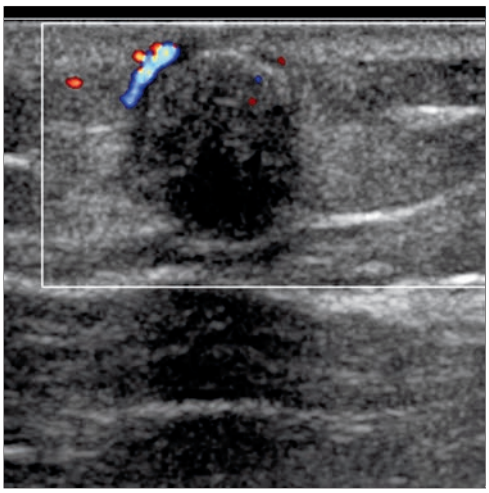


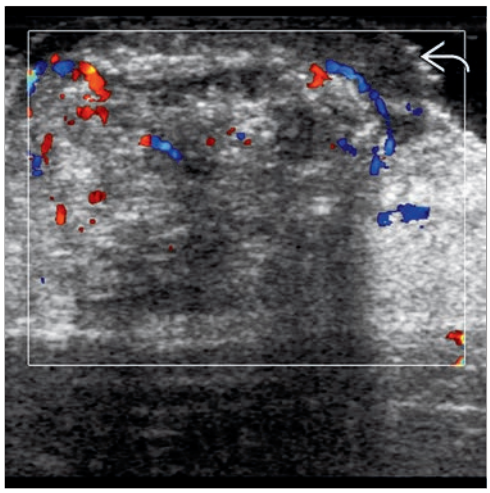
(Left) *Transverse ultrasound of the same pilomatricoma as previous image shows a heterogeneous subcutaneous mass containing multiple lumpy calcifications associated with moderate posterior shadowing. Note the hypoechoic peripheral rim.* ***(Right)*** *Axial T2WI MR of the same pilomatricoma shows a well-defined subcutaneous mass on the posteromedial aspect of the arm. The lesion is attached to the dermis and contains some low-signal areas due to internal calcification.*



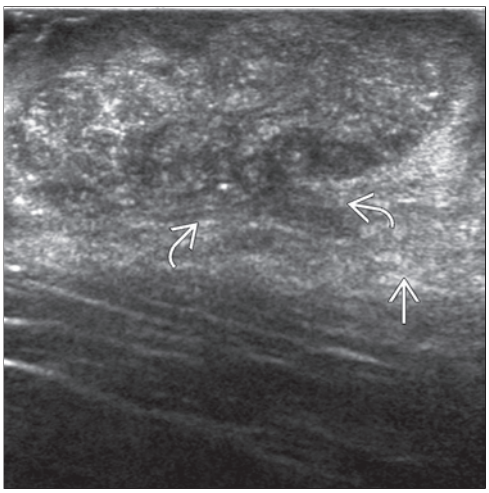


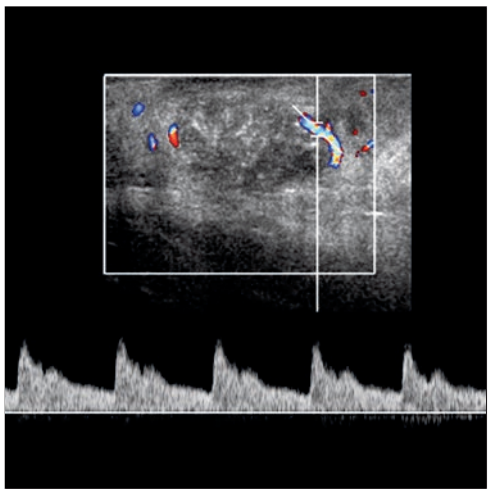
PILOMATRICOMA



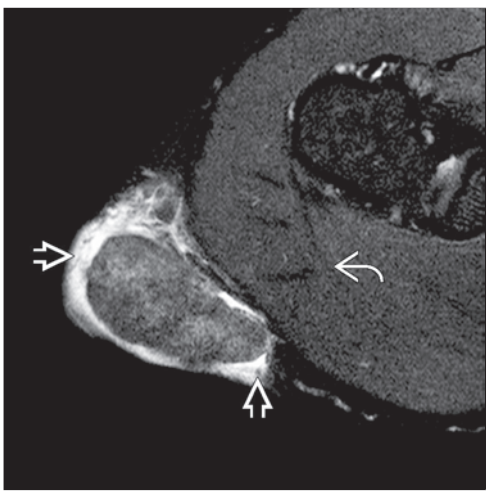


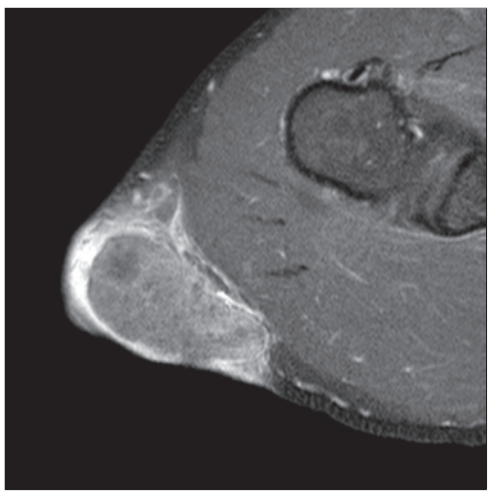
(Left) *Transverse color Doppler ultrasound of a young boy shows a round hypoechoic pilomatricoma with peripheral arc-like calcification and mild peripheral vascularity. Moderate posterior acoustic shadowing is present.* ***(Right)*** *Longitudinal color Doppler ultrasound of an adult male shows a protruding ⇄, ovoid, heterogeneous calcified pilomatricoma with dermal attachment in the arm region. Mild central and peripheral vascularity are present. Note the moderate posterior shadowing.*





(Left) *Longitudinal ultrasound of a 20 year old shows an irregular ovoid pilomatricoma with small internal calcified foci and minimal posterior acoustic shadowing. There seems to be localized rupture at the posterior margin of the tumor ⇄. Mild perilesional edema ⇄ is present.* ***(Right)*** *Longitudinal pulsed Doppler ultrasound of the same lesion shows intratumoral arterial vascularity. Intrinsic vascularity is present in 1/2 of all pilomatricoma tumors.*





(Left) *Axial T2WI FS MR shows a well-defined, ovoid, predominantly hypointense pilomatricoma in the subcutaneous fat of the posterior deltoid ⇄ region. The lesion is hypointense due to matrix calcification. There is a rim of T2 hyperintensity ⇄ in the soft tissue indicative of peritumoral edema.* ***(Right)*** *Axial T1WI C+ FS MR of the same lesion shows mild tumoral enhancement. Moderate peritumoral enhancement is consistent with peritumoral inflammation, most likely due to capsular leakage.*

DERMATOFIBROSARCOMA PROTUBERANS

Key Facts

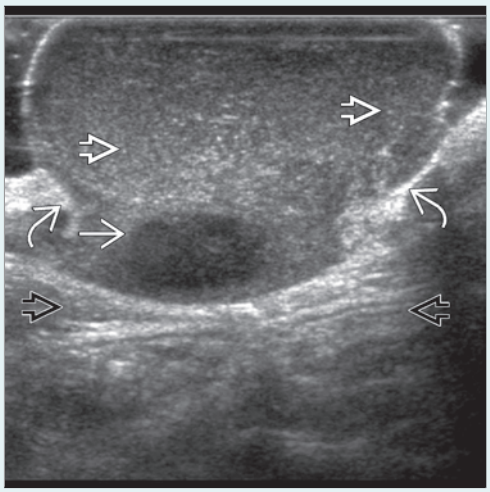
Terminology
- Low-grade spindle cell mesenchymal sarcoma of dermis and subcutis

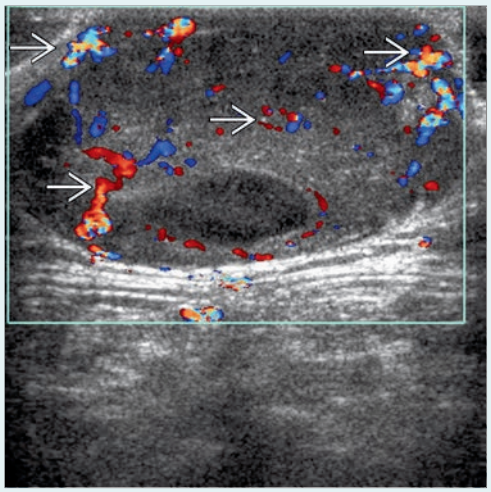
Imaging
- Nearly always arising from dermis, then infiltrates subcutaneous tissue
- Most commonly arise in trunk (~ 50%), particularly chest wall, back, abdominal wall
- Protruding mass arising from skin with bluish or reddish discoloration
- Well marginated, subcutaneous
- Slightly lobulated border
- Hypoechoic with posterior enhancement
- Small echogenic speckles and larger discrete hypoechoic cleft-like areas within mass
- Central and peripheral organized vascularity
- Ultrasound helps to characterize tumor type as well as assess local infiltration

Top Differential Diagnoses
- Malignant skin lesions: Metastasis or cutaneous lymphoma

Clinical Issues
- Slowly growing, slowly evolving cutaneous mass
- Starts as a small nodule, grows into a medium-erythematous or bluish lesion
- Cutaneous ulceration and satellite nodules in advanced lesions
- Occasionally, plaque-like indurated region progressing to single or multiple protuberant nodules
- Locally infiltrative
- Uncommonly metastasize (3-5%)

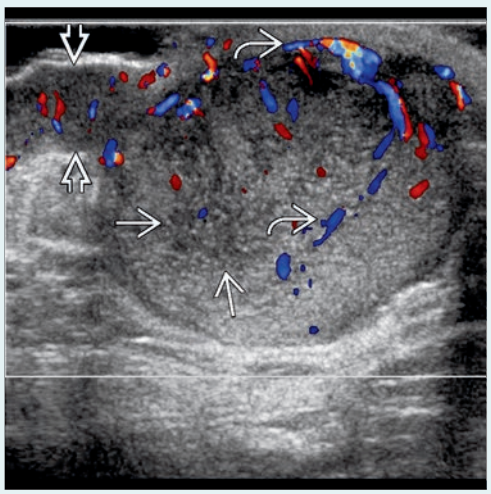
(Left) *Transverse ultrasound shows a typical dermatofibrosarcoma protuberans (DFSP). The hypoechoic lesion is arising from the dermis and superficial subcutaneous layer and shows mild posterior acoustic enhancement. The tumor has a lobulated deeper margin. There is an eccentric hypoechoic area and tiny hyperechoic foci within the tumor matrix, which are also typical for DFSP.* ***(Right)*** *Transverse color Doppler ultrasound of the same patient shows typical central and peripheral vascularity.*





(Left) *Clinical photo of the same patient shows the typical clinical appearance of DFSP. The reddish mass protrudes from the skin through a narrow stalk. No ulceration is present.* ***(Right)*** *Transverse color Doppler ultrasound shows typical appearances of DFSP. This tumor has a finger-like appendage and small, irregular, hypoechoic areas. Central and peripheral vascularity is present.*





DERMATOFIBROSARCOMA PROTUBERANS

TERMINOLOGY

Abbreviations
- Dermatofibrosarcoma protuberans (DFSP)

Definitions
- Low-grade spindle cell mesenchymal sarcoma of dermis and subdermis

IMAGING

General Features
- Best diagnostic clue
  - Nearly always arises in dermis then infiltrates subcutaneous tissue
- Location
  - Most commonly arises in trunk (~ 50%), particularly chest wall, back, abdominal wall
  - Next common site is proximal extremities (35-40%)
- Size
  - Ranges from 1 cm to > 25 cm; averages 4 cm at time of excision
- Morphology
  - Protruding mass arising from skin with bluish or reddish discoloration

Ultrasonographic Findings
- Grayscale ultrasound
  - Subcutaneous, well marginated
  - Slightly lobulated border
  - Hypoechoic with posterior enhancement
  - Small hyperechoic foci and discrete cleft-like areas of hypoechogenicity within mass
- Color Doppler
  - Central and peripheral organized vascularity

CT Findings
- Usually well-defined with distinct lobular or nodular architecture
- Attenuation equal to or slightly higher than that of skeletal muscle
- Central cystic component (myxoid degeneration, necrosis, or hemorrhage) uncommon
- No calcification, moderate contrast enhancement

MR Findings
- Isointense to hyperintense relative to muscle on T1WI
- Hyperintense relative to muscle on fluid-sensitive sequences

Imaging Recommendations
- Best imaging tool
  - Ultrasound is helpful to characterize tumor type as well as assess degree of local infiltration

DIFFERENTIAL DIAGNOSIS

Malignant Skin Lesions
- Metastasis or cutaneous lymphoma
  - More infiltrative appearance
  - Sometimes only differentiated by histology

PATHOLOGY

Gross Pathologic & Surgical Features
- Indurated plaque or nodule involving dermis and subcutaneous layers with firm, gray-white cut surface
  - Tumor infiltration from dermis tends to be asymmetrical with frond-like horizontal or vertical extensions into subcutaneous fat
  - ± ulceration of cutaneous margin

Microscopic Features
- Histopathology varies within lesion
  - Central regions: Spindle-shaped cells in storiform pattern with myxoid change
  - Peripheral regions: Hypocellular with dermal collagen separating spindle cells
  - Deep regions: Spindle cells expanding fibrous septa and interdigitating with fat
- Morphological variants: Pigmented, myofibroblastic, granular cell, purely or predominantly myxoid tumor
- Focal sarcomatous transformation ~ 10%

CLINICAL ISSUES

Presentation
- Most common signs/symptoms
  - Slowly growing, slowly evolving cutaneous mass
    - Starts as a small nodule, grows into a medium-sized erythematous or bluish lesion
    - Ulceration and satellite nodules in advanced lesions
    - Occasionally, plaque-like indurated region progressing to single or multiple protuberant nodules
  - Usually presents clinically several years after initial occurrence due to slow insidious growth
- Other signs/symptoms
  - Pain and bleeding with large lesions

Demographics
- Age
  - Young to middle-aged adults
  - Peak in 3rd to 5th decades of life
- Gender
  - Male predominance
- Epidemiology
  - Most common primary sarcoma in subcutaneous tissues, 6% of all soft tissue sarcomas

Natural History & Prognosis
- Local recurrence in 18-55% depending on completeness of initial excision
- Metastatic disease is rare (3-6%) and usually in those cases with focal sarcomatous transformation
  - Metastases (when present) involve lungs in 75%

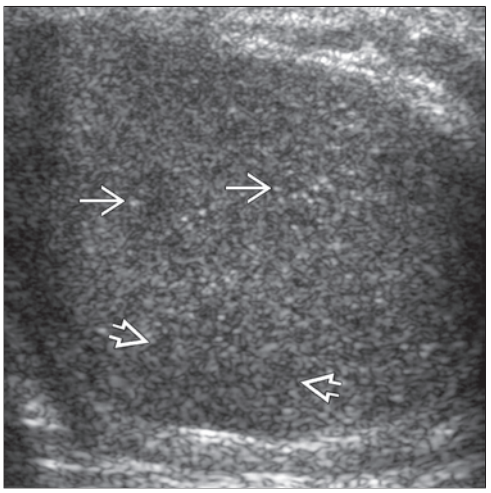
Treatment
- En bloc resection with wide surgical excision (≥ 3 cm margin)

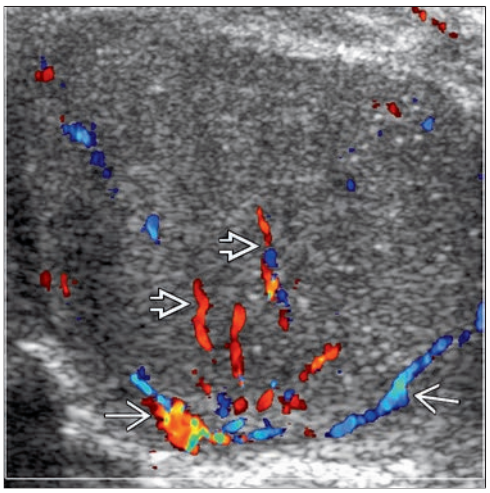
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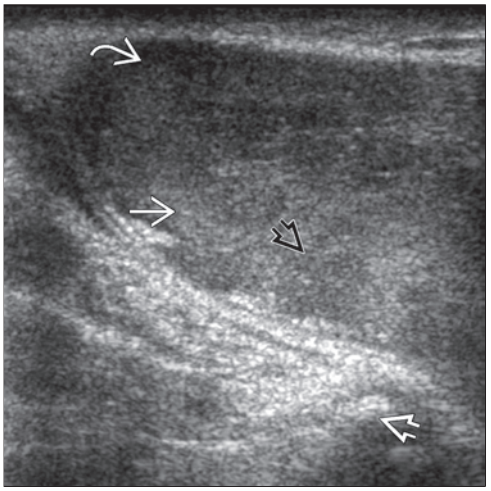
DERMATOFIBROSARCOMA PROTUBERANS

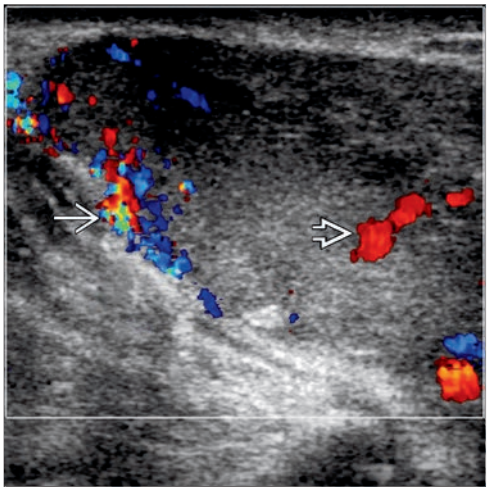
(Left) *Transverse ultrasound of DFSP shows typical tiny hyperechoic foci and central small irregular cleft-like hypoechoic areas.* ***(Right)*** *Transverse color Doppler ultrasound of the same tumor shows typical vascular pattern of DFSP with both peripheral and inwardly radiating central vascularity.*



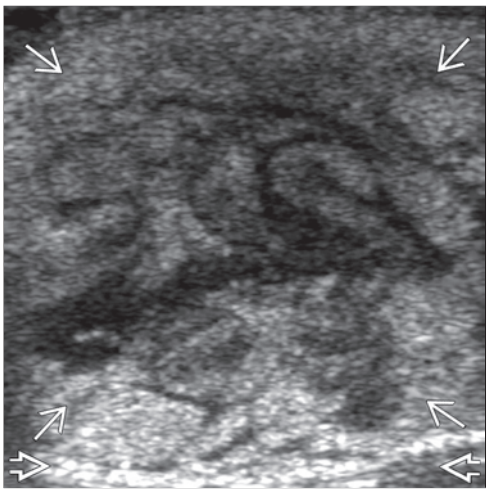


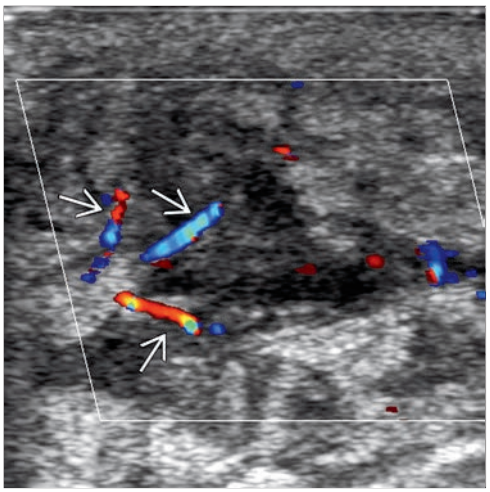
(Left) *Transverse ultrasound shows a DFSP of the lumbar region. The mass lies in the superficial subcutaneous and dermal regions and is hypoechoic with posterior acoustic enhancement. Typical tiny hyperechoic foci and small cleft-like hypoechoic areas are present within the lesion.* ***(Right)*** *Transverse color Doppler ultrasound of the same tumor shows predominantly peripheral vascularity and inwardly radiating central vascularity.*

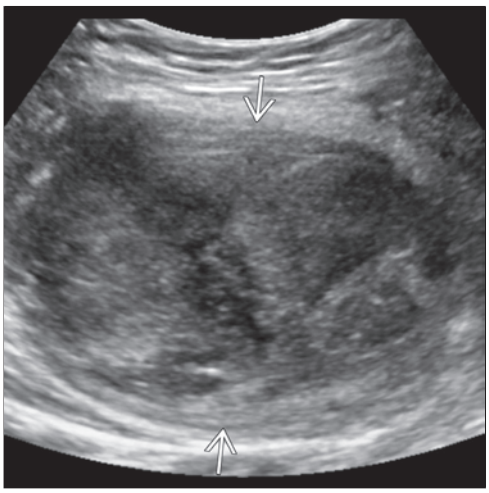


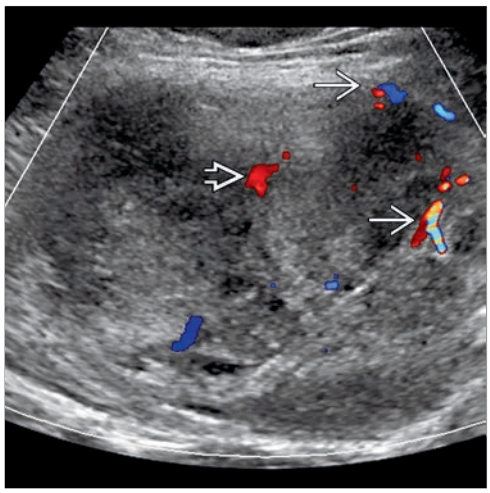


(Left) *Transverse ultrasound shows atypical appearances of DFSP in that it is very ill defined and infiltrating the dermal and subcutaneous regions. The lesion is hypoechoic with posterior acoustic enhancement.* ***(Right)*** *Transverse color Doppler ultrasound of the same tumor shows predominantly central vascularity.*

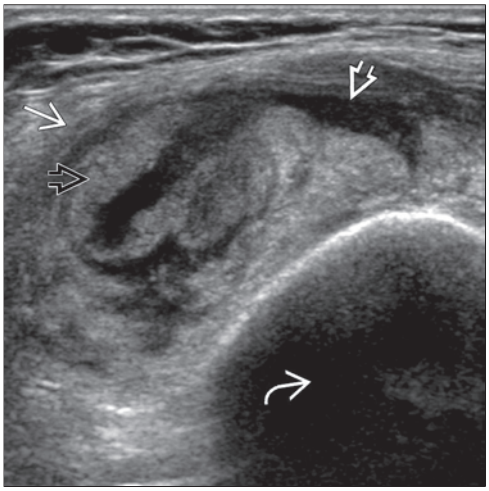


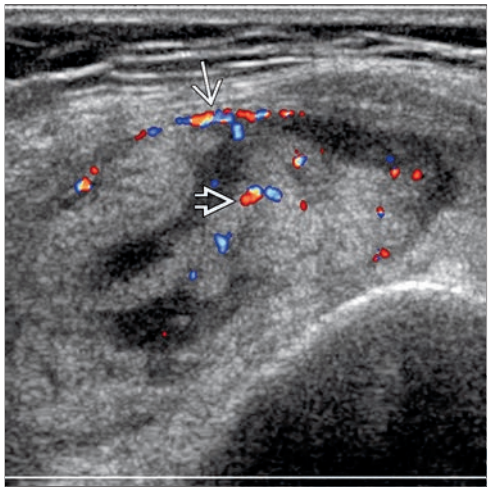




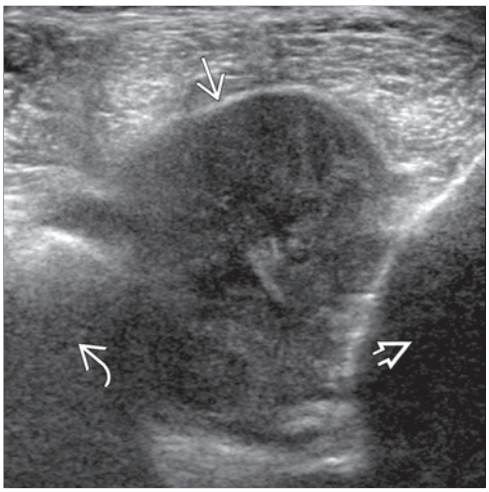


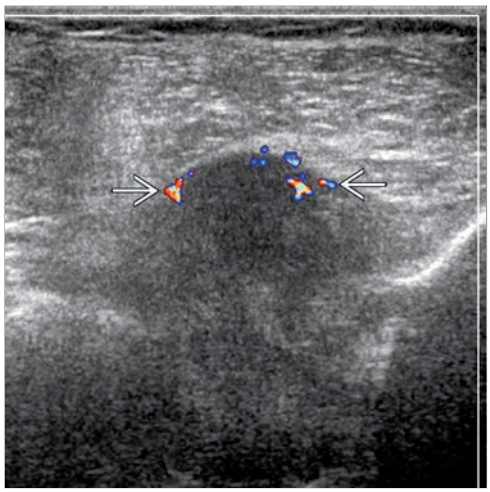
(Left) *Transverse ultrasound shows a large DFSP with sarcomatous change in the deeper part of the tumor. While this example appears similar to other DFSP tumors on ultrasound, histology revealed focal sarcomatous transformation.* ***(Right)*** *Transverse color Doppler ultrasound of the same patient shows central and peripheral internal vascularity. No atypical vascular pattern is present to suggest the sarcomatous change though the histology showed areas of sarcomatous change.*





(Left) *Transverse ultrasound shows a DFSP in the deep subcutaneous tissue anterior to the tibia. This lesion is atypical in echogenicity in that it contains mixed hypoechoic and hyperechoic areas.* ***(Right)*** *Transverse color Doppler ultrasound of the same tumor shows both central and peripheral vascularity.*





(Left) *Transverse ultrasound of the same patient as previous image shows another DFSP in the muscle between the tibia and the fibula. The deep location is atypical. However, the ultrasound appearances are characteristic of DFSP though areas of sarcomatous change were evident on histology.* ***(Right)*** *Transverse color Doppler ultrasound of the same tumor patient shows only mild peripheral vascularity.*

VASCULAR LEIOMYOMA

Key Facts

Terminology
- Benign solitary smooth muscle neoplasm that most commonly occurs in subcutaneous tissues of lower extremities

Imaging
- 2/3 involve lower leg or ankle
- Majority are < 2 cm in diameter and subcutaneous
- Well-defined smooth margin
- Usually round or ovoid in shape
- Long axis parallel to extremity axis
- Hypoechoic, homogeneous
- No perceivable capsule
- Mild to moderate posterior enhancement
- Occurs in close proximity to artery or vein
- Hypervascular with peripheral vascular convergence

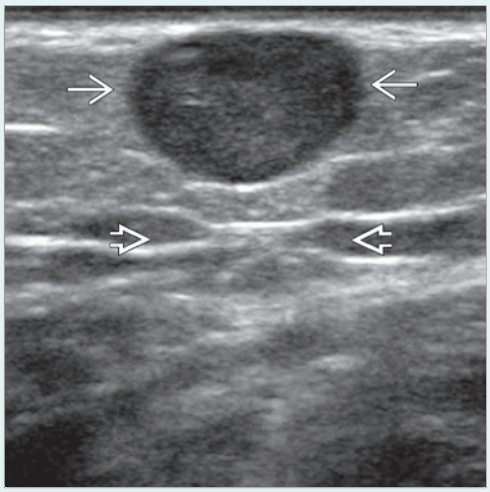
Top Differential Diagnoses
- Peripheral nerve sheath tumor

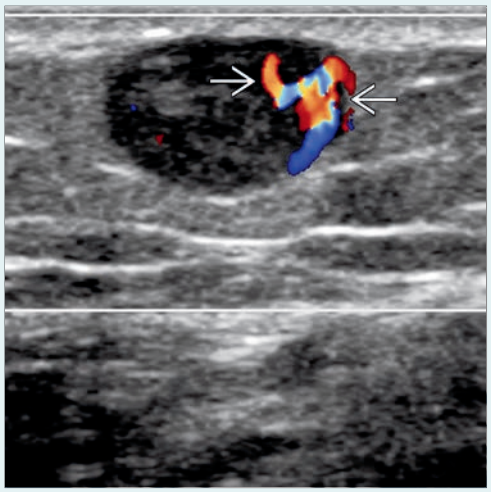
Pathology
- Arises from muscularis media of small arteries or veins

Clinical Issues
- Often painful or tender
- Most commonly present in middle age
- Slight female predominance

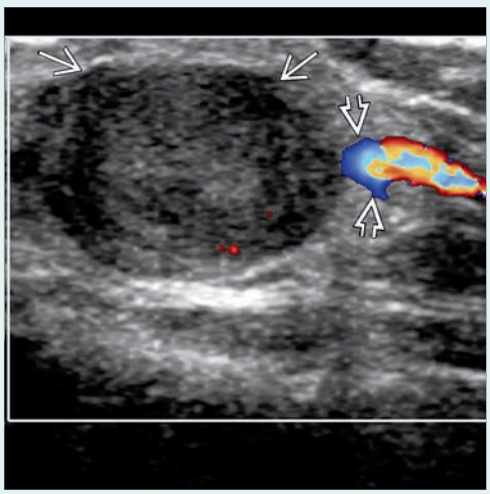
Diagnostic Checklist
- Very similar to small peripheral nerve sheath tumors, which do not necessarily possess thickened entering or exiting nerves
  - Thus, consider vascular leiomyoma in differential diagnosis of small peripheral nerve sheath tumor, particularly if located in lower leg or ankle

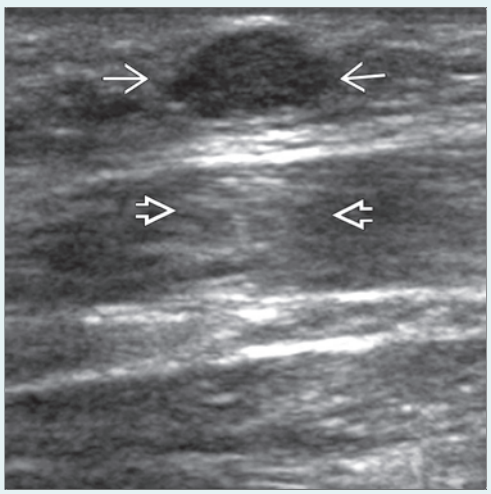
(Left) *Transverse ultrasound of the thigh shows the typical appearance of a vascular leiomyoma. A well-defined, hypoechoic, oval-shaped mass located in the superficial subcutaneous and deep dermal layers of the lower limb. There is mild posterior acoustic enhancement.* ***(Right)*** *Transverse color Doppler ultrasound of the same patient shows peripheral vascularity within the lesion with vessels converging to a single point (vessel convergence).*





(Left) *Transverse color Doppler ultrasound shows a typical vascular leiomyoma. The tumor lies close to a prominent subcutaneous vessel, which is one of the distinguishing features of vascular leiomyoma. This should not be confused with a thickened entering or exiting nerve.* ***(Right)*** *Transverse ultrasound shows a small subcutaneous vascular leiomyoma with a mildly lobulated border and moderate acoustic enhancement. The lesion is small, but the appearance is still reasonably characteristic.*





VASCULAR LEIOMYOMA

TERMINOLOGY

Synonyms
- Angioleiomyoma, angiomyoma

Definitions
- Benign solitary smooth muscle neoplasm arising from muscular layer of small arteries or veins

IMAGING

General Features
- Location
  - Any location; 2/3 occur around lower leg or ankle
  - Lower leg and ankle > thigh > upper extremity > head and neck > trunk
- Size
  - Majority < 2 cm in diameter
- Morphology
  - Usually roundish or ovoid in shape

Ultrasonographic Findings
- Grayscale ultrasound
  - Small (< 2 cm), roundish or oval-shaped mass
  - Subcutaneous > dermal > subfascial
  - Well-defined smooth margin
  - Long axis parallel to extremity axis
  - Hypoechoic, homogeneous
  - No perceivable capsule
  - Mild to moderate posterior acoustic enhancement
  - Occurs in close proximity to vessels
  - ± calcific foci
  - ± anechoic foci of myxoid accumulation
  - May also have hemorrhagic or lipomatous component
- Color Doppler
  - Hypervascular with high-resistance flow
    - Typically several vessels converge to a single point at tumor periphery

CT Findings
- Well-defined mass with similar attenuation to muscle
- ± calcification

MR Findings
- T1WI
  - Isointense to mildly hyperintense to muscle
- T2WI
  - Heterogeneously hyperintense to muscle
- T1WI C+
  - Variable enhancement depending on subtype
  - Located adjacent to vessels
  - Similar appearance to peripheral nerve sheath tumor

Imaging Recommendations
- Best imaging tool
  - Ultrasound: Can usually either allow specific diagnosis or at least limit list of differential diagnoses

DIFFERENTIAL DIAGNOSIS

Benign Peripheral Nerve Sheath Tumor
- ± thickening of entering or exiting nerve
- More prominent myxoid areas, chaotic vascular pattern

PATHOLOGY

General Features
- Etiology
  - Benign smooth muscle neoplasm that arises from muscular layer of small arteries or veins
- Genetics
  - No consistent chromosomal abnormality

Gross Pathologic & Surgical Features
- Solitary, pseudoencapsulated, gray-white myxoid mass

Microscopic Features
- Mass comprises medium-sized thin-walled venous-like vessels and thick-walled arterial-like vessels that otherwise lack typical features of veins or arteries
  - Walls of these vessels merge imperceptibly with a proliferative mass of benign smooth muscle
- Absent or infrequent mitoses
- 3 broad histologic subtypes depending on amount of smooth muscle and type of vessel present (solid, venous, cavernous)
- ± myxoid areas, calcification, hemorrhage, or fat

CLINICAL ISSUES

Presentation
- Most common signs/symptoms
  - Often (> 50%) painful or tender
    - Symptoms are affected by light touch, temperature, or hormonal change
    - Upper extremity lesions are less likely to be painful than lower extremity lesions
  - Grows slowly over several years

Demographics
- Age
  - Any age, but most common in middle-aged adults
- Gender
  - F:M = 1.7:1
- Epidemiology
  - Uncommon, ~ 5% of benign soft tissue tumors

Natural History & Prognosis
- No spontaneous regression

Treatment
- Complete marginal surgical excision

DIAGNOSTIC CHECKLIST

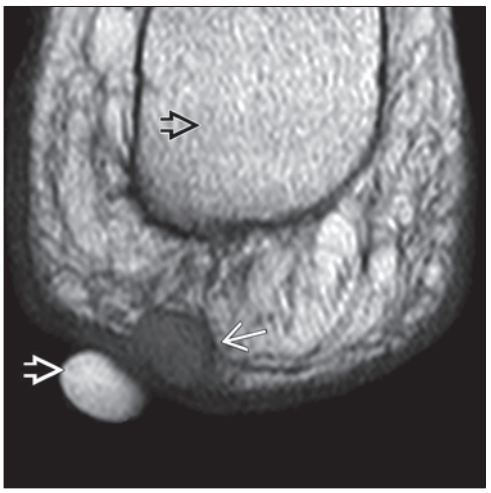
Image Interpretation Pearls
- Well-defined, small, hypoechoic vascular mass within subcutaneous tissue of lower extremity
  - Consider vascular leiomyoma in same differential as small peripheral nerve sheath tumor

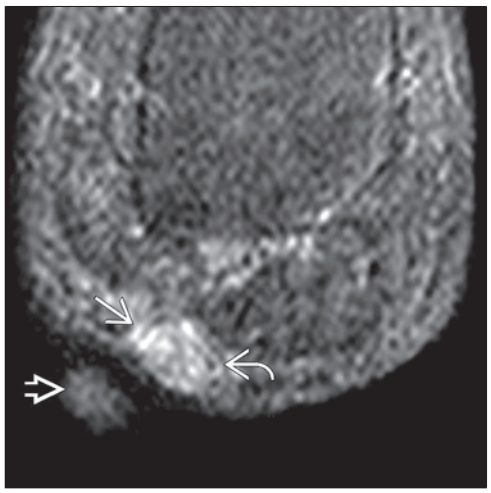
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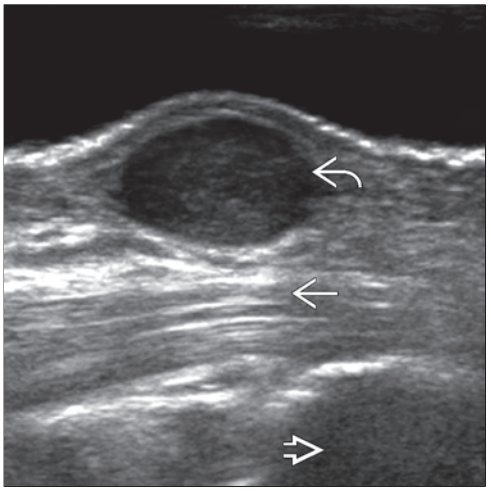
VASCULAR LEIOMYOMA

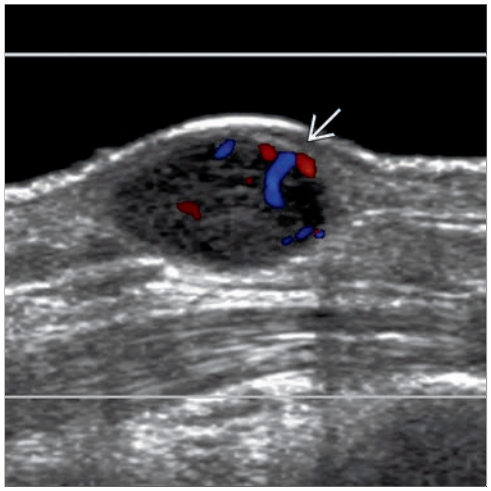
(Left) *Coronal T1WI FSE MR shows a well-defined subcutaneous vascular leiomyoma in the heel region beneath the calcaneum. The lesion is uniformly hypointense and located in the dermal tissues protruding into the subcutaneous layer. There is an overlying skin marker.* ***(Right)*** *Coronal T2WI FS MR of the same tumor shows that the vascular leiomyoma is quite hyperintense. Some small peripheral hypointense foci may represent vascular voids. The skin marker is visible.*



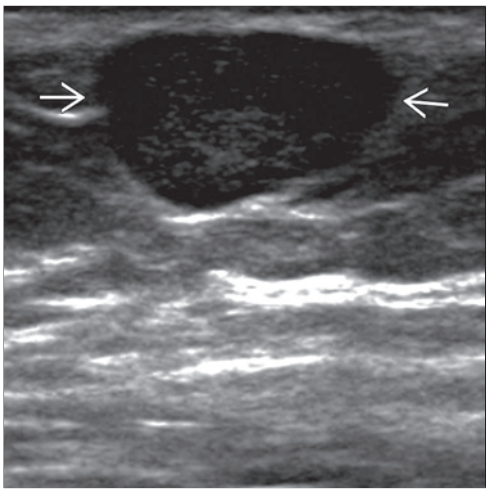


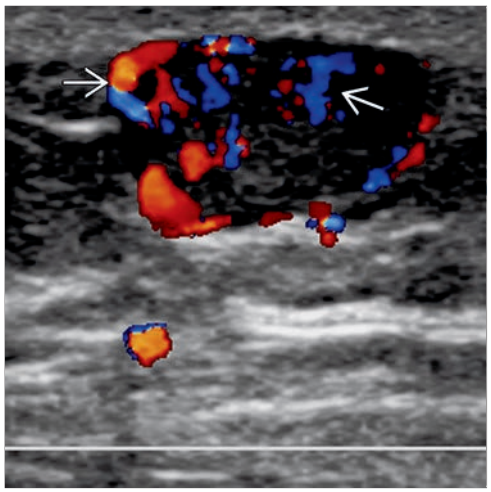
(Left) *Longitudinal ultrasound shows a subcutaneous vascular leiomyoma in the foot with a typical hypoechoic echotexture, no visible capsule, and moderate posterior acoustic enhancement. The head of the 1st metatarsal bone is shown.* ***(Right)*** *Longitudinal color Doppler ultrasound of the same lesion reveals mild vascularity with vessels tending to converge towards the periphery.*



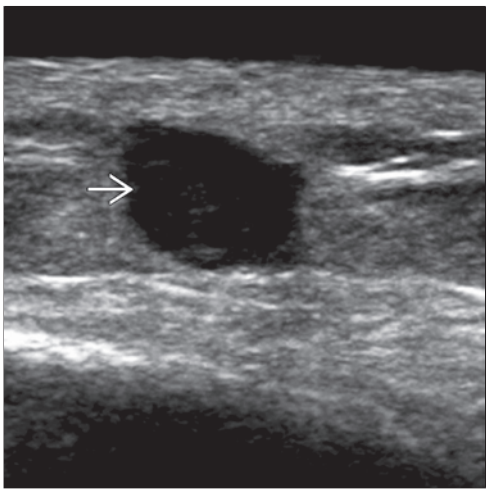


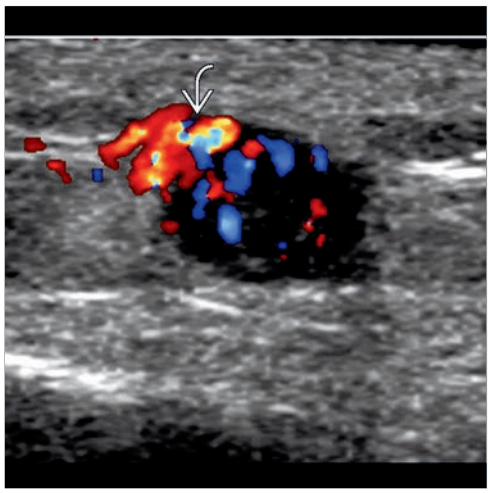
(Left) *Transverse ultrasound shows a large (> 2 cm in size) subcutaneous vascular leiomyoma at the ankle. The lesion is very hypoechoic, with a smooth lobulated border and no perceivable capsule, all suggestive of vascular leiomyoma.* ***(Right)*** *Transverse color Doppler ultrasound of the same patient shows moderate central and peripheral vascularity without any particular vascular convergence in this case.*



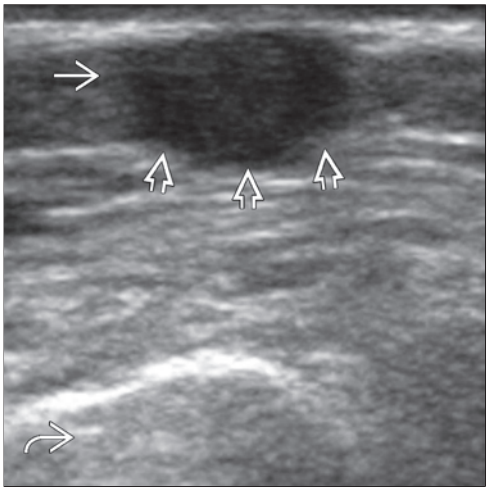


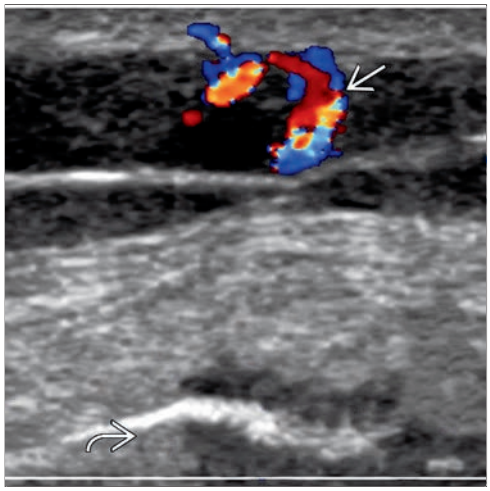
VASCULAR LEIOMYOMA



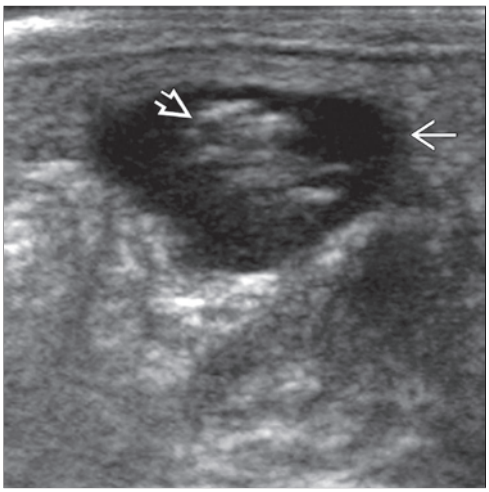


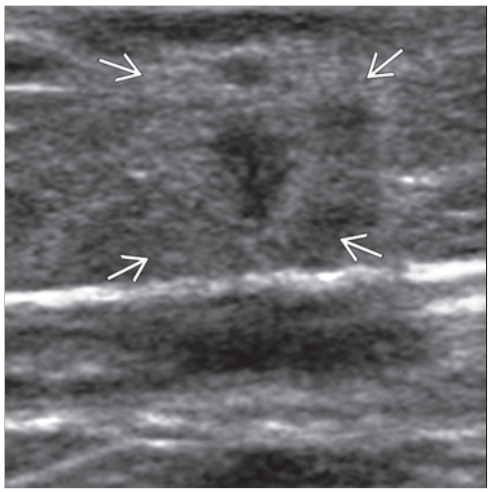
(Left) *Transverse ultrasound shows a subcutaneous vascular leiomyoma in the ankle region with a lobulated and mildly angular border. Note the characteristic hypoechoic echotexture of the vascular leiomyoma.* ***(Right)*** *Transverse color Doppler ultrasound of the same tumor reveals moderate peripheral and central vascularity and vascular convergence to a peripheral area.*





(Left) *Transverse ultrasound shows a subcutaneous vascular leiomyoma in the shin that abuts the investing fascia. This is likely to be a feature of vascular leiomyomas located in areas with thin subcutaneous tissue. The underlying tibia is shown.* ***(Right)*** *Transverse color Doppler ultrasound of the same lesion shows moderate peripheral vascularity. No particular vascular convergence is evident. The underlying tibia is shown.*





(Left) *Transverse ultrasound shows atypical, histologically proven vascular leiomyoma within the subcutaneous tissues of the thigh. The vascular leiomyoma is large (> 2 cm in diameter). It has central calcification, which is an uncommon, though recognized, feature of vascular leiomyoma.* ***(Right)*** *Transverse ultrasound shows an atypical subcutaneous vascular leiomyoma in the ankle region. This histologically proven tumor has an ill-defined border with an echogenic lipomatous-like periphery.*

SUPERFICIAL METASTASES, LYMPHOMA, AND MELANOMA

Key Facts

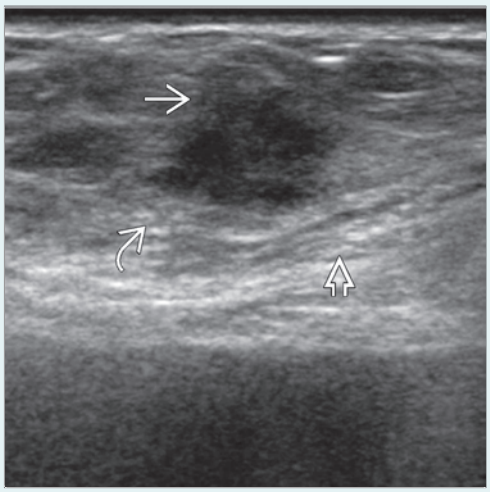
Terminology
- "Superficial" refers to tissues above investing fascia

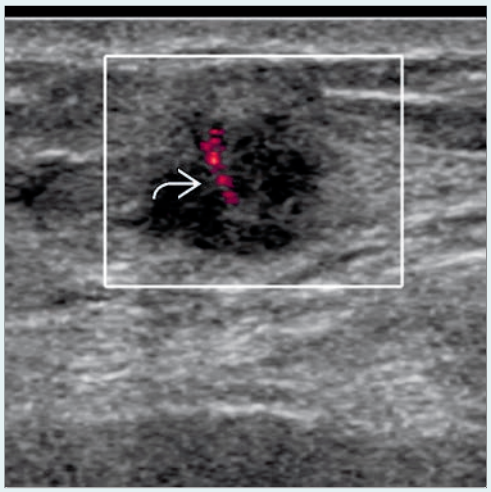
Imaging
- Familiarity with imaging characteristics of recognizable superficial soft tissue tumors is key to recognizing malignant tumor
  - One of the best criterion of malignant superficial tumor (metastases, lymphoma, melanoma, etc) is that the appearance does not conform to the recognized appearance of benign superficial tumor (lipoma, vascular anomaly, epidermoid cyst, etc)
- Well-demarcated, irregular margin
- Hypoechoic mass with melanoma metastases often being markedly hypoechoic

Pathology
- 5% of superficial tumors are malignant
- 50% of these are metastatic
  - Most common (> 50%) from breast, bronchus, lung, and melanoma
  - Adenocarcinoma (~ 40%) > squamous cell carcinoma > melanoma
- Remaining 50% are lymphoma, primary sarcoma of superficial tissues, dermatofibrosarcoma protuberans

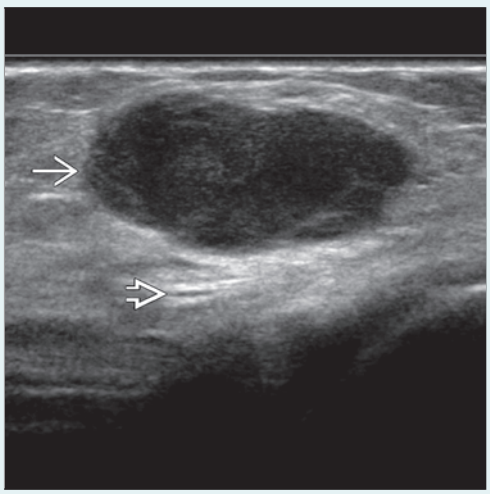
Clinical Issues
- Superficial mass in patient with known malignancy is still more commonly benign than malignant
  - Superficial metastasis can rarely be 1st manifestation of occult malignancy in 0.8%

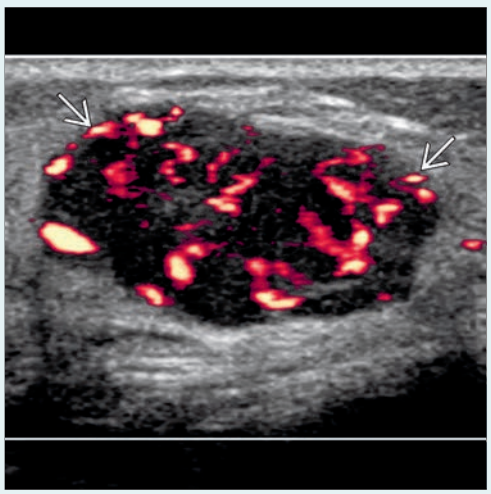
(Left) *Longitudinal ultrasound shows a subcutaneous metastatic nodule of the anterior chest wall in a patient with disseminated carcinoma of the lungs. The nodule is irregular in outline with a mild degree of perilesional edema. It abuts the atrophic pectoralis muscles.* ***(Right)*** *Transverse power Doppler ultrasound of the same tumor shows mild intrinsic vascularity. Carcinoma of the lungs is one of the most common malignancies to metastasize to the superficial tissues.*





(Left) *Longitudinal ultrasound shows a well-defined, oval, subcutaneous metastasis in the anterior chest wall in a patient with lower limb melanoma. The metastatic lesion is markedly hypoechoic and associated with moderate posterior acoustic enhancement.* ***(Right)*** *Longitudinal power Doppler ultrasound of the same tumor shows moderate to high intrinsic vascularity with a chaotic and mainly peripheral vascular pattern.*





SUPERFICIAL METASTASES, LYMPHOMA, AND MELANOMA

TERMINOLOGY

Synonyms
- Superficial metastasis, skin metastasis, cutaneous metastasis, subcutaneous metastasis, secondary deposits, metastatic tumor

Definitions
- Spread of tumor from its primary site to skin or subcutaneous tissues
- "Superficial" refers to tissues above investing fascia (subcutaneous and cutaneous tissues)

IMAGING

General Features
- Best diagnostic clue
  - Hypoechoic, superficial soft tissue mass with intrinsic vascularity
- Location
  - Trunk (> 50%) >> head and neck > extremities
- Size
  - Variable; mean ~ 2 cm
- Morphology
  - Well-defined to infiltrative mass

Radiographic Findings
- Radiography
  - Usually not seen on radiograph
  - Soft tissue swelling if large size

CT Findings
- Isodense to hypodense to muscle
- Variable enhancement

MR Findings
- T1WI
  - Usually isointense to hypointense to muscle on T1WI
    - Areas of T1 hyperintensity may be seen in melanoma due to paramagnetic effect of melanin and hemorrhage
- T2WI
  - Variable; homogeneous to heterogeneously hyperintense to hypointense to skeletal muscle
- T1WI C+
  - Variable enhancement
    - Homogeneous, heterogeneous, nodular, or ring enhancement

Ultrasonographic Findings
- Ultrasound appearance does not conform with known appearances of benign superficial tumors (e.g., lipoma, vascular anomaly, nerve sheath tumor, epidermoid cyst, etc.)
- **Shape**
  - Usually round or oval
    - Elongated shape is seen in melanoma due to tumor spreading along lymphatic channels
- **Margin**
  - Usually well-demarcated, irregular margin
    - Smooth border may be seen but is less specific
- **Echogenicity**
  - Most are hypoechoic
    - Marked hypoechogenicity in melanoma due to poor beam reflection of melanin
- **Internal architecture**
  - Homogeneous or heterogeneous
  - Cystic areas are seen in melanoma, squamous cell tumor, or other cystic/necrotic primary
  - Calcification from calcified or ossified primary tumor such as osteosarcoma, medullary carcinoma of thyroid, or mucinous adenocarcinoma
- **Vascularity**
  - Mild to moderate intrinsic vascularity is usually present
  - Peripheral vascularity is more specific
  - Moderate to high intrinsic vascularity is seen in metastases from hypervascular primary tumors such as melanoma and renal cell carcinoma
- **Perittumoral change**
  - Some degree of peritumoral edema is usually present
  - ± posterior enhancement
  - ± posterior shadowing
- Ultrasound is useful in assessing locoregional spread of melanoma
  - Primary melanoma tumors are uncommonly imaged
  - Satellite tumor: Tumor arising ≤ 3 cm from primary tumor or its scar
  - In-transit tumor: Tumor arising ≥ 3 cm from primary tumor or scar along lymphatic course toward regional lymphatic nodes
  - Interval lymph node metastases: Metastasis of lymph node along path from primary tumor to regional lymph node station, e.g., epitrochlear node or popliteal node
  - Regional lymph node metastasis: Metastasis of regional nodes, e.g., ipsilateral inguinal group for lower limb melanoma, ipsilateral axillary group for upper limb melanoma
  - Distant cutaneous metastasis: Hematogenous metastasis to cutaneous or subcutaneous tissues

Imaging Recommendations
- Best imaging tool
  - Ultrasound
    - All superficial tumors are readily accessible to high-resolution ultrasound
    - Allows good definition of tumor characteristics
    - Most superficial soft tissue tumors can be diagnosed on imaging characteristics alone without need for histological confirmation
      - However, suspected malignant tumor needs histological confirmation
    - Familiarity with imaging characteristics of recognizable superficial soft tissue tumors is key to recognizing malignant tumor
      - One of the best criterion of malignant superficial tumor is that appearance does not conform to recognized appearances of any benign tumor
    - Ultrasound diagnosis of tumor type is based, not on 1 or 2 ultrasound signs, but on the relative strength of multiple recognized ultrasound signs interpreted in conjunction with clinical presentation
- Protocol advice
  - Ultrasound for assessment of superficial masses
    - Apply light transducer pressure to avoid compression or distortion of mass

SUPERFICIAL METASTASES, LYMPHOMA, AND MELANOMA

- Especially for color Doppler imaging to avoid blanching of tumoral vascularity
- Grayscale for assessment of shape, margin, echogenicity, internal architecture, and peritumoral changes
- Color Doppler for assessment of tumoral and peritumoral vascularity
- Melanoma assessment comprises assessment of primary tumor site as well as satellite tumor, in-transit tumor, regional nodes, and (when clinically suspect) distant cutaneous metastases
- Ultrasound-guided fine-needle aspiration for cytology (FNAC) or biopsy for histology
- CT, PET/CT, or whole-body MR for systemic staging

DIFFERENTIAL DIAGNOSIS

Soft Tissue Sarcoma
- Very uncommon in superficial tissues
- Usually > 5 cm
- Can look very similar to metastases
  - Epithelioid sarcoma mimics metastatic carcinoma histologically

Nerve Sheath Tumor
- Entering and exiting nerve
- Fusiform or oblong-shaped
- Smooth border

Lymph Node
- Fatty hilum, hilar vascularity
- Along lymphatic drainage pathway
- Malignant nodes are more rounded, more hypoechoic with loss of fatty hilum, and have chaotic, predominantly peripheral vascular pattern

Hematoma
- Organizing hematoma can have variable hyperemia
- Interval resolution rather than progression

Soft Tissue Abscess
- Irregular peripheral hyperemia
- Localized signs of infection

PATHOLOGY

General Features
- 5% of superficial soft tissue tumors are malignant
  - 50% of these are metastatic
  - Metastatic tumor cell type
    - Most common: Adenocarcinoma (~ 40%)
    - Followed by squamous cell carcinoma and melanoma
    - Less common: Sarcoma or carcinosarcoma
    - Primary tumor
      - Breast (> 50%) > lung > melanoma
  - 50% are nonmetastatic
    - Lymphoma, primary sarcoma of superficial tissues, dermatofibrosarcoma protuberans
  - Lymphoid malignancies are classified as T-cell neoplasms, B-cell neoplasms & Hodgkin disease
    - T-cell neoplasms are divided into precursor T-cell neoplasms and peripheral T-cell neoplasms
    - Subcutaneous panniculitis-like T-cell lymphoma is an uncommon type of peripheral T-cell lymphoma
  - Overall, about 30% of lymphoma are extranodal (spleen, gastrointestinal, salivary glands, thymus, thyroid, lung, genitourinary, pancreas, liver, adrenal, breast, and musculoskeletal)
    - Most musculoskeletal involvement is to bone and muscle
    - Involvement of superficial tissues is uncommon
    - Most cases of superficial lymphoma have known systemic lymphoma
      - Rarely, lymphoma involving superficial tissues may precede diagnosis of systemic lymphoma

CLINICAL ISSUES

Presentation
- Most common signs/symptoms
  - Superficial nodule
  - Often have history of known malignancy
    - Superficial mass in patient with known malignancy is still more commonly benign
    - Superficial metastases can be 1st manifestation of occult malignancy in 0.8%
  - Superficial metastases are generally more painful than primary soft tissue sarcoma

Demographics
- Age
  - Any; mean: 53
- Gender
  - M = F

Natural History & Prognosis
- Superficial metastases indicate stage IV disease regardless of primary tumor or location

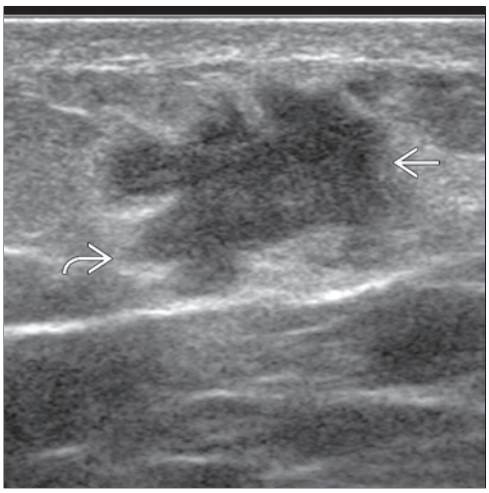
Treatment
- Highly variable depending on site of primary tumor and degree of metastatic spread
- Primary sarcoma of superficial tissues is treated with wide local excision

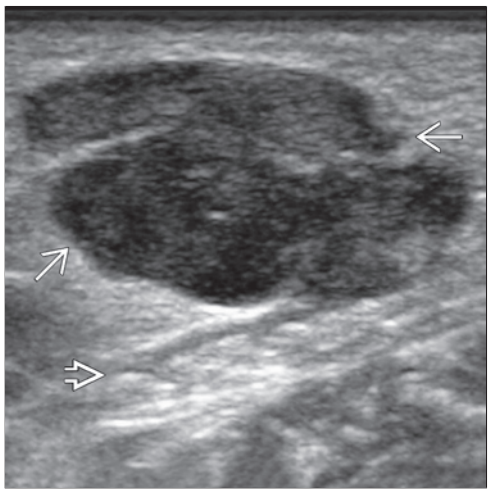
DIAGNOSTIC CHECKLIST

Consider
- Superficial malignant tumor if ultrasound appearances do not conform to recognized appearances of benign tumor (e.g., lipoma, vascular anomaly, epidermoid cyst, nerve sheath tumor)
- Superficial mass in patient with known malignancy is still more commonly benign rather than malignant

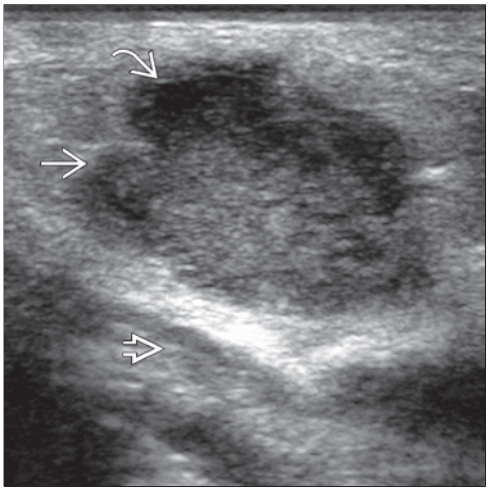
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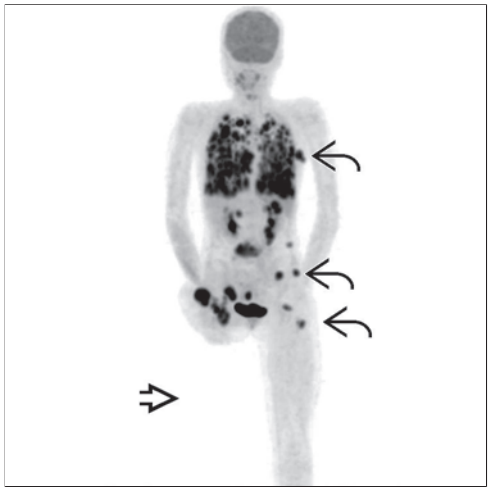
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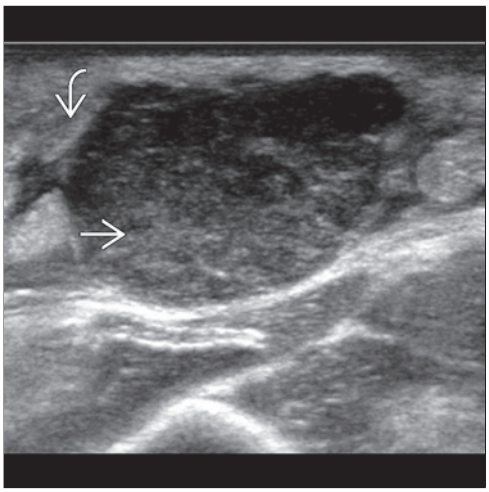


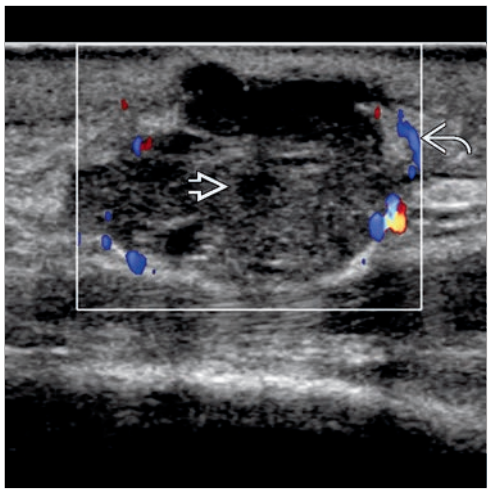
(Left) *Longitudinal ultrasound shows an irregular metastatic nodule* ➔ *in the subcutaneous tissue of the flank from a clear cell sarcoma in the foot. The border is very irregular with moderate peritumoral edema* ➔. ***(Right)*** *Longitudinal ultrasound shows an irregularly lobulated, hypoechoic, subcutaneous metastatic nodule* ➔ *of the abdominal wall from a malignant nerve sheath tumor in the calf. Mild posterior acoustic enhancement* ➔ *is present.*





(Left) *Longitudinal ultrasound of the axillary tail in a patient with high-grade conventional osteosarcoma of the knee shows an irregular, subcutaneous metastatic nodule* ➔. *Note the anechoic areas* ➔ *and moderate posterior acoustic enhancement* ➔. ***(Right)*** *Coronal PET image of the same patient shows amputation of right lower limb* ➔ *with disseminated metastases to the lungs, lymph nodes, and soft tissues* ➔.

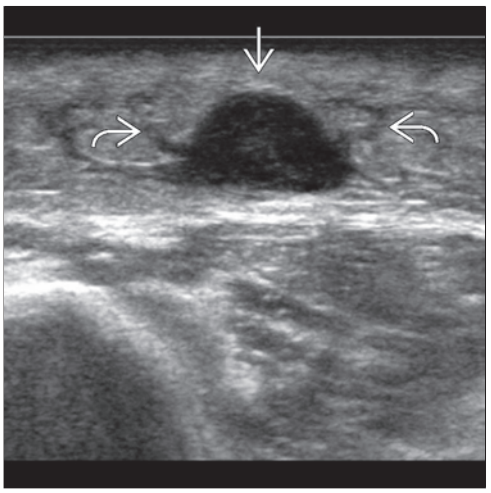


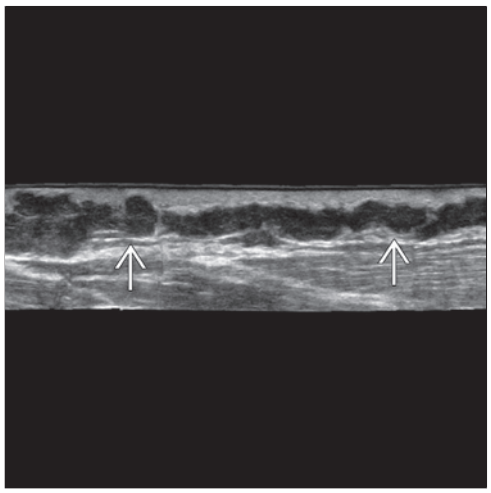


(Left) *Transverse ultrasound of the forearm in a patient with malignant melanoma of the ipsilateral index finger shows a lobulated hypoechoic subcutaneous mass* ➔. *Note the severe degree of surrounding soft tissue swelling* ➔ *due to lymphoedema.* ***(Right)*** *Transverse color Doppler ultrasound of the same tumor shows mild peripheral vascularity* ➔. *The tumor is > 3 cm from the primary tumor and hence represents an in-transit lesion. There is a small cystic component* ➔ *centrally.*

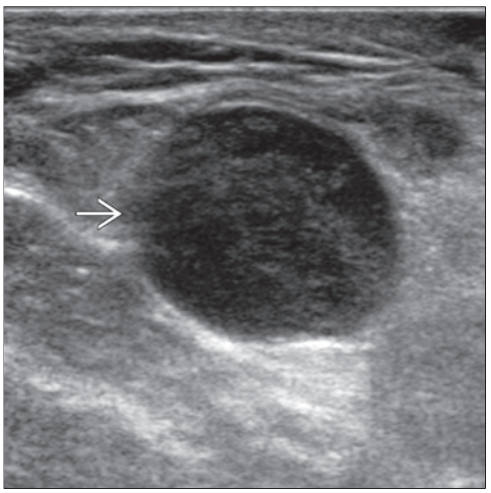
SUPERFICIAL METASTASES, LYMPHOMA, AND MELANOMA

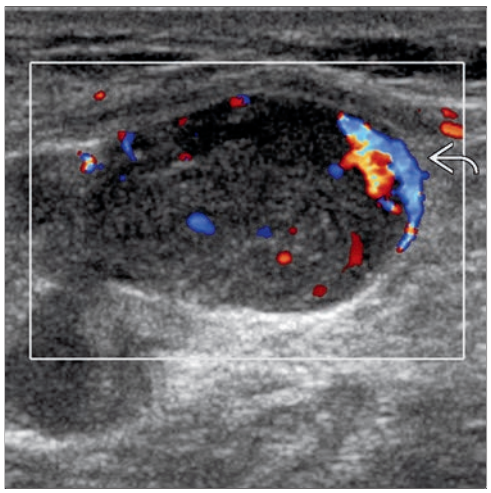
(Left) *Transverse ultrasound of the same patient as previous image shows another smaller in-transit lesion ➔ in the forearm. There are hypoechoic bands ➔ at both the proximal and distal ends of this tumor due to dilated lymphatics.* ***(Right)*** *Longitudinal ultrasound of the same patient shows another much longer in-transit lesion ➔. The elongated, hypoechoic mass is due to tumor filling and distending a lymphatic channel between the primary tumor and the regional lymph nodes.*



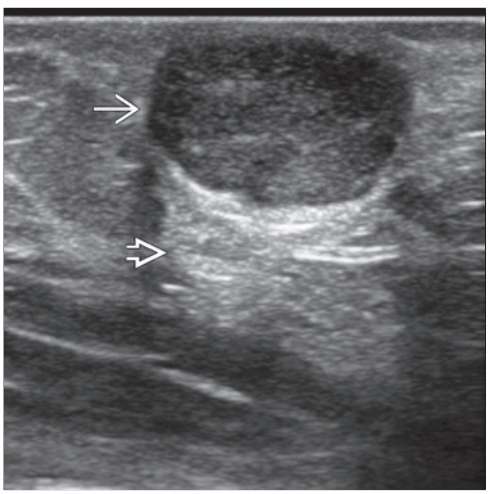


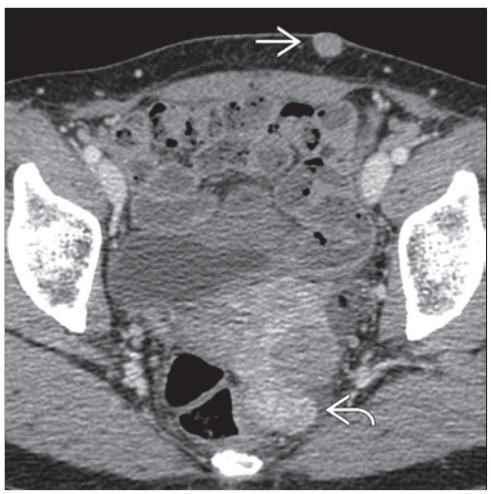
(Left) *Transverse ultrasound shows a metastatic hypoechoic groin lymph node ➔ in a patient with melanoma of the big toe. The lymph node is enlarged and rounded with loss of the normal fatty hilum.* ***(Right)*** *Longitudinal color Doppler ultrasound of the same lymph node shows moderate severity, chaotic-type, predominantly capsular vascular pattern ➔. No hemorrhage, which may be a feature of melanoma nodes, is evident in this lymph node.*

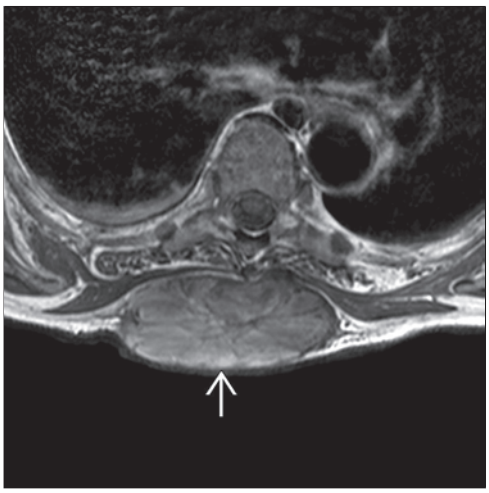


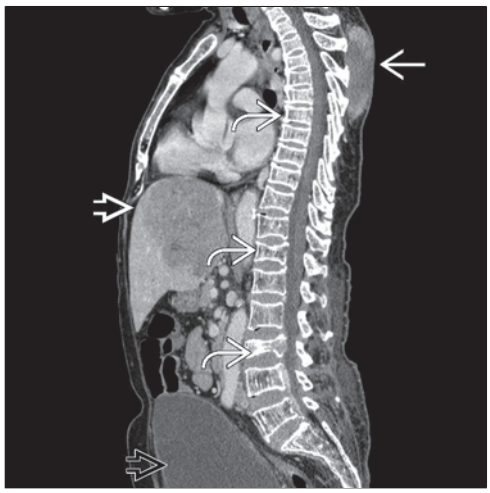


(Left) *Longitudinal ultrasound of the abdominal wall in a patient with metastatic melanoma shows a well-defined hypoechoic subcutaneous nodule ➔ with moderate posterior acoustic enhancement ➔.* ***(Right)*** *Axial CECT of the same patient shows the well-defined, mildly enhancing metastatic tumor ➔ in the anterior abdominal wall. There is a larger metastatic intraperitoneal deposit ➔ in the pouch of Douglas.*



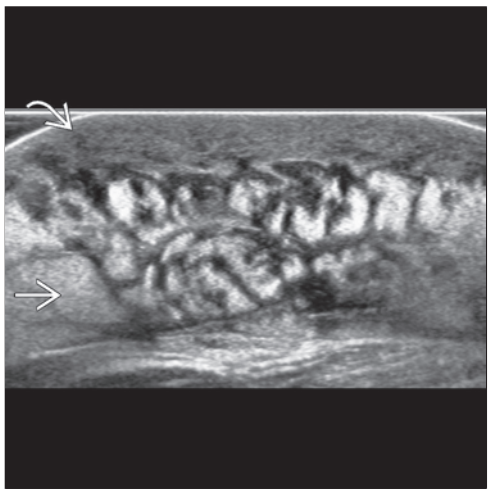




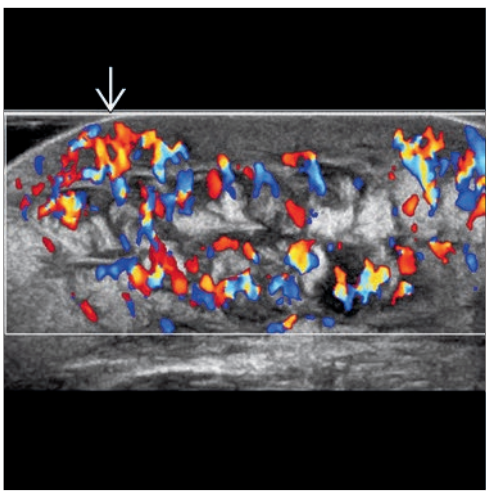


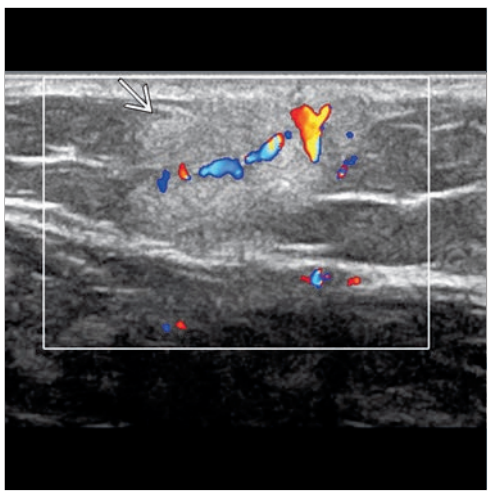
(Left) *Axial T1WI MR shows a large metastatic melanoma deposit* ➔ *in the subcutaneous tissues dorsal to the thoracic spine. The mass is hyperintense to muscle due to the presence of melanin.* ***(Right)*** *Sagittal CECT of the same patient shows the mildly enhancing heterogeneous thoracic subcutaneous metastasis* ➔*. There is a large hepatic metastasis* ➔*, and multiple vertebral fractures* ➔ *with cauda equina compression and urinary retention* ➔*.*





(Left) *Clinical photograph shows a patient with increasing calf swelling and erythema* ➔ *for 1 month. The patient was otherwise healthy.* ***(Right)*** *Longitudinal ultrasound of the same patient shows a large area of quite well-defined, intense subcutaneous* ➔ *and cutaneous* ➔ *edema and swelling. No discrete tumor mass is present. The edematous swollen subcutaneous tissue is lobulated while the subdermal tissue is diffusely swollen without lobulation.*





(Left) *Longitudinal color Doppler ultrasound of the same patient shows severe lesional hyperemia* ➔*. Initially this was thought to represent an unusual infective panniculitis. Biopsy, however, revealed peripheral T-cell malignant lymphoma.* ***(Right)*** *Longitudinal color Doppler ultrasound in the same patient at a site just proximal shows a hyperechoic, mildly vascular subcutaneous and subdermal mass* ➔*, also due to T-cell lymphoma. This smaller lesion was clinically occult.*

VASCULAR ANOMALY

Key Facts

Terminology

- Term "vascular anomaly" includes both hemangioma & vascular malformation
- Hemangioma is benign vascular tumor
  - Grows after birth, proliferates, & then involutes
  - Most are low flow
- Vascular malformation is vascular dysplastic lesion
  - Present at birth, grows commensurately with child & with no proliferation or involution
  - Low flow: Venous malformation, capillary-venous, capillary, lymphatic
  - High flow: Arteriovenous malformation, arteriovenous fistula

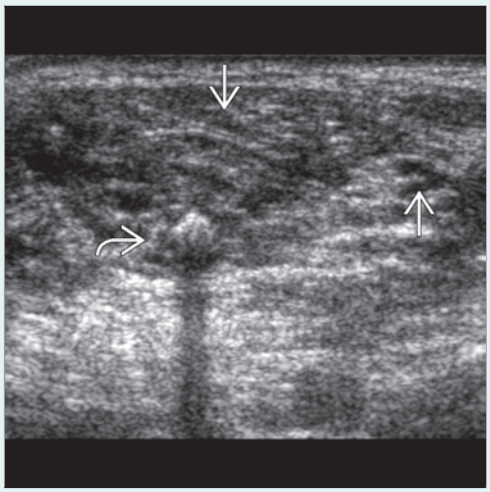
Imaging

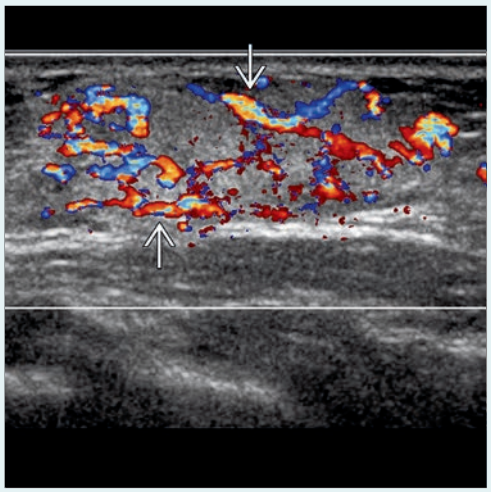
- Fairly discrete usually hypervascular mass ± phleboliths ± medium to large vascular channels
- Variable amount of stromal connective tissue component
  - This stromal component may contain microvessels too small to resolve with ultrasound
- Variable color depending on speed of flow
  - Grayscale is better at detecting very slow flow
- Use ultrasound to make diagnosis & assess flow
  - Histological confirmation is not usually necessary
- Use MR to define extent, if lesion is large

Diagnostic Checklist

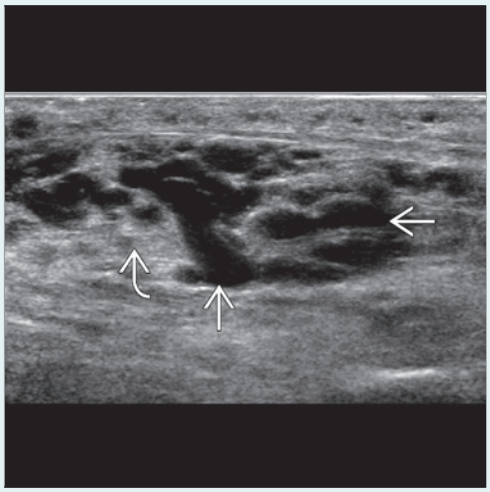
- Consider age at onset, behavior, size, extent, vascular vs. connective tissue stromal component, high flow vs. low flow
- Differentiation between hemangioma & vascular malformation is not always clear-cut despite imaging, clinical, & even histological evaluation
- Chronological behavior is best way of differentiating hemangioma from vascular malformation

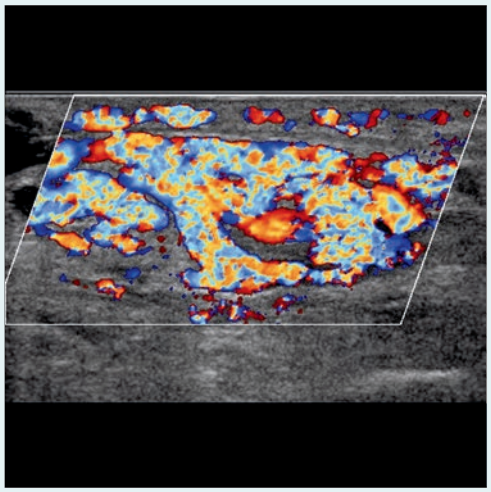
(Left) *Transverse ultrasound shows a venous malformation with multiple small tubular spaces representing dilated vascular channels and a phlebolith with strong acoustic shadowing.* ***(Right)*** *Transverse color Doppler ultrasound of a 4-month-old infant shows a subcutaneous hemangioma with multiple arterial vascular channels embedded within a fatty stroma. This fatty stroma may contain additional small vascular channels too small to be resolved on ultrasound.*





(Left) *Longitudinal ultrasound shows an arteriovenous malformation composed mainly of dilated vascular channels and only a relatively small amount of supporting stroma.* ***(Right)*** *Color Doppler ultrasound of the same lesion shows the presence of predominant arterial channels, more indicative of a high-flow arteriovenous malformation than of a hemangioma, which generally tend to have venous-type flow.*





VASCULAR ANOMALY

TERMINOLOGY

Definitions

- Term "vascular anomaly" comprises both hemangioma & vascular malformation
  - Differentiation based on cellular turnover, histologic features, natural history, & physical findings
- Hemangioma
  - Benign vascular tumors of infancy & childhood
    - Feature cellular proliferation & hyperplasia
  - Grows after birth
  - Characterized by early proliferative stage & later involuting stage
- Vascular malformation
  - Vascular dysplasia rather than actual tumor
    - Dysplastic vascular channels with normal endothelial turnover
  - Present at birth & grows commensurately with child without proliferation or involution
  - Classified according to predominant vessel type as venous, capillary, arterial, lymphatic, or combined type
    - Venous malformation is most common type
    - Combined types: Arteriovenous malformation, arteriovenous fistula, capillary-venous, lymphatic-venous, etc.
  - Can also be subclassified as low flow or high flow depending on flow dynamics
    - Low-flow vascular malformation: Venous, capillary, lymphatic, capillary-venous, or capillary-lymphatic-venous
    - High-flow vascular malformation: Arteriovenous malformation, arteriovenous fistula

IMAGING

General Features

- Best diagnostic clue
  - ↑ vascular channels ± fairly discrete mass ± phleboliths
- Location
  - Head & neck (including intracranial) (40%), trunk (20%), & extremities (40%)
  - Unifocal (97%) or multifocal (3%)
- Morphology
  - Single vessel ectasia → discrete well-defined mass → large ill-defined advancing collection of anomalous vessels

Radiographic Findings

- Radiography
  - Soft tissue mass ± phleboliths ± reactive mature periosteal new bone formation

MR Findings

- T2WI FS
  - Extent is well demonstrated
    - T2 hyperintense
  - Low flow: No signal voids or large feeding arteries
  - High flow: Signal voids ± large feeding arteries
- MRA
  - Better at revealing nidus of arteriovenous malformation than ultrasound or MR
    - Shows feeding artery & draining vein

Ultrasonographic Findings

- Ultrasound appearances vary greatly but ultrasound diagnosis of vascular anomaly can still be reliably made in most cases
- Diagnosis is based on compendium of signs rather than only 1 or 2 signs
  - Differentiation between hemangioma & vascular malformation can be very difficult based on imaging alone
- Abnormal vascular spaces may appear as vascular channels or large cystic spaces
- Variable stromal connective tissue component but usually have fatty-type background
  - Background connective tissue may contain numerous capillaries too small to be resolved with ultrasound
- Acoustic shadowing from phleboliths
- Color Doppler imaging varies depending on speed of flow
  - Slow blood flow shows moving echoes on real-time grayscale imaging often with little or no flow on color Doppler imaging
- Hemangioma
  - Solid hypervascular mass ± lobulation ± numerous vascular channels ± cavernous veins ± phleboliths ± feeding arteries or draining veins
  - Usually low flow
- Venous malformation
  - Very similar to hemangioma
    - Slow or no flow on color Doppler imaging
    - Can also detect arterial supply in venous malformation
      - 1 or 2 arteries do not imply high-flow lesion
- Capillary malformation
  - Localized echogenic mass though not with typical lipoma features
    - Usually minimal or no vascularity evident
- Lymphatic malformation
  - Largely avascular
  - Macrocystic (i.e., cystic hygroma): Thin-walled, septated, fluid-filled cystic spaces
    - ± internal echoes (hemorrhage or infection)
  - Microcystic: Multiple tiny cysts within echogenic connective tissue matrix
    - Cysts may be too small to be resolved with ultrasound
- Arteriovenous malformation
  - Pulsatile mass on grayscale imaging
  - High-velocity flow on spectral & color Doppler imaging
  - Only type of vascular malformation to possess nidus
    - Nidus is clear epicenter of anomaly from which the lesion spreads peripherally

Angiographic Findings

- Prelude to sclerotherapy or embolization

Imaging Recommendations

- Best imaging tool
  - Use ultrasound to make diagnosis & assess flow
  - Use MR to define extent of large lesions
- Protocol advice
  - Use minimal transducer pressure to avoid compression

VASCULAR ANOMALY

- Determine location, size, extent, & margin
- Assess flow dynamics
  - High flow or low flow depending on predominant flow pattern
    - 1-2 feeding arteries may be found in low-flow lesions
- Gauge amount of connective tissue stroma vs. vascular component

DIFFERENTIAL DIAGNOSIS

Alveolar Soft Part Sarcoma

- Most commonly develops in 2nd or 3rd decade, particularly in lower limbs
- Typically, intramuscular hypervascular mass
  - Similar to high-flow vascular malformation
  - Grows more rapidly clinically & on serial imaging
  - Metastases (nodal, lung) in 20% of patients at presentation

Nerve Sheath Tumor

- Hypoechoic with echo-poor areas
  - ± entering or exiting nerve

PATHOLOGY

General Features

- Associated abnormalities
  - Maffucci syndrome
    - Enchondromas & low-flow vascular malformations
  - Osler-Weber-Rendu syndrome
    - Arteriovenous malformations in skin, mucosa, lung, & brain
  - Klippel-Trenaunay-Weber syndrome
    - Low-flow vascular malformation ± large aberrant lateral vein ± limb hypertrophy
  - Gorham-Scott syndrome
    - Intraosseous venous & lymphatic malformations

Microscopic Features

- Hemangioma: Plump endothelial cells with hypercellularity, especially during proliferative phase
  - Extracellular matrix contains growth-promoting proteins
- Vascular malformation: Flat endothelial cells with normal cell turnover
  - Patchy deficiency of smooth muscle in wall → dilatation
  - Extracellular matrix does not contain growth promoting proteins
- Even histologically, distinction between vascular anomalies can be difficult

CLINICAL ISSUES

Presentation

- Most common signs/symptoms
  - Pain, swelling
- Other signs/symptoms
  - Bluish discoloration, mass ± engorgement with gravity
  - Discomfort after exercise, edema, hemorrhage, local hypertrophy, ulceration, contractures

Demographics

- Age
  - Vascular anomalies are present at birth & become clinically apparent at varying times
    - Hemangioma: Present 1st month of life
    - Venous malformation: Birth to early adulthood
    - Capillary, lymphatic malformation: First 2 years of life
    - Arteriovenous malformation: Early teens
- Epidemiology
  - Prevalence: 1.5% of general population
  - Hemangioma: Most common tumor of childhood
  - Vascular malformation: Venous (60%), lymphatic (25%), arteriovenous (10%), mixed (10%), & capillary (5%),

Natural History & Prognosis

- Hemangioma
  - Proliferation (months) → stabilization (months to years) → spontaneous involution
  - ± biphasic proliferative phase
    - Involute at rate of 10% per year
  - Residual cosmetic deformity in ~ 50%
    - Later involution → greater cosmetic deformity
- Vascular malformation
  - Grows slowly proportional to patient growth
    - ± more rapid growth precipitated by puberty, pregnancy, infection, trauma, or unknown factor
    - Arteriovenous malformation is unpredictable
    - Threatens limb & life
  - Lymphatic malformation may spontaneously regress

Treatment

- Hemangioma: Wait-and-see, steroids, propranolol, laser, or surgery
- Vascular malformation
  - Sclerotherapy
    - Angiographic, venographic, or US guidance
      - Ethanol is most commonly used sclerosing agent
    - Contraindicated if high flow (risk of systemic shunting)
  - Coil embolization for high-flow malformation
- Wide surgical excision
  - ± preoperative or postoperative embolization/ sclerotherapy
  - High morbidity & recurrence rates

DIAGNOSTIC CHECKLIST

Consider

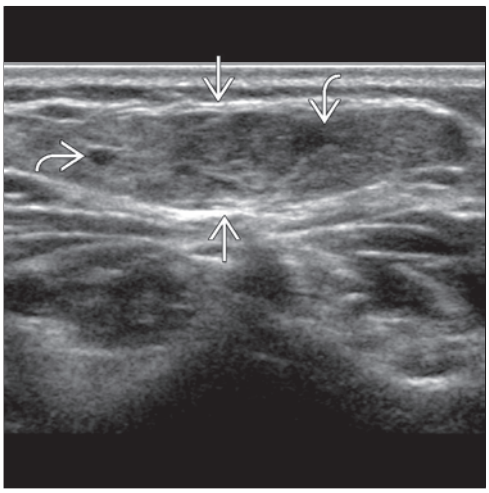
- Treatment based on clinical & imaging features
  - Classification is not always clear-cut despite imaging, clinical, & even histological evaluation

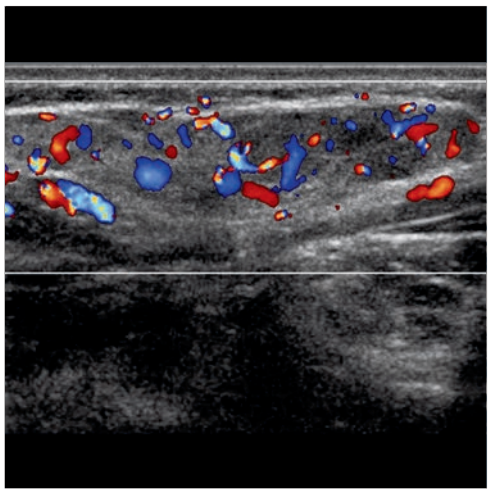
Image Interpretation Pearls

- Important parameters to assess: Age at onset, behavior, site, size, margination, vascular vs. stromal component, & high flow vs. low flow

SELECTED REFERENCES

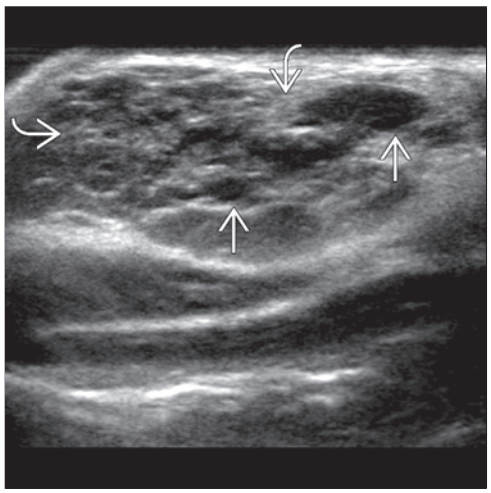
1. Dubois J et al: Vascular anomalies: what a radiologist needs to know. Pediatr Radiol. 40(6):895-905, 2010



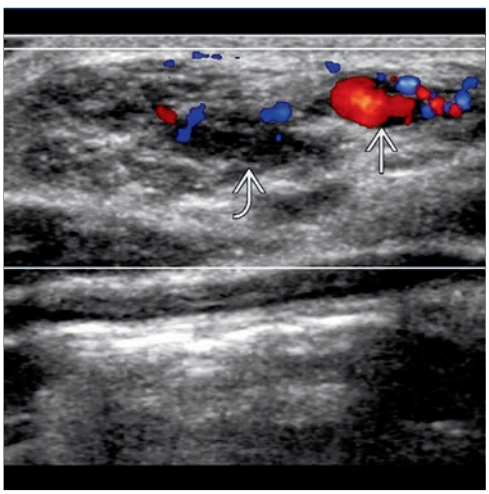


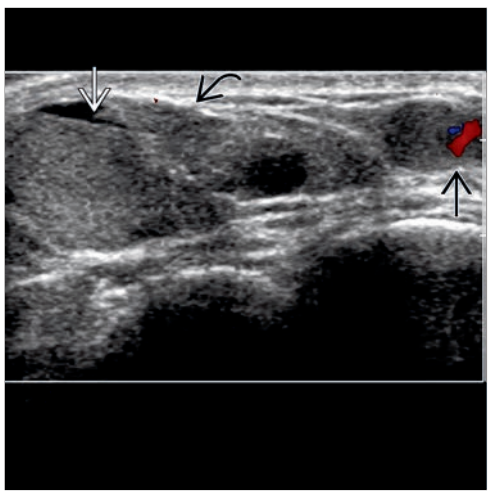
(Left) *Transverse ultrasound of the upper back in 1-year-old child shows a well-defined hyperechoic subcutaneous mass* ➔. *Multiple small hypoechoic vascular channels* ➔ *are present within the mass.* ***(Right)*** *Color Doppler ultrasound of the same lesion shows multiple dilated venous-type vascular channels within the mass, indicative of a slow-flow infantile hemangioma. These lesions would usually be followed up by serial ultrasound examination.*





(Left) *Clinical photo of a 6-year-old child shows a protuberant epigastric mass* ➔ *with minimal bluish discoloration of the overlying skin.* ***(Right)*** *Transverse ultrasound of the same lesion shows a subcutaneous mass composed of ~ 70% abnormally dilated vascular channels* ➔ *and 30% echogenic stromal component* ➔. *Grayscale appearances are those of a venous-type vascular malformation or hemangioma. Clinical progress will allow distinction between these 2 entities.*

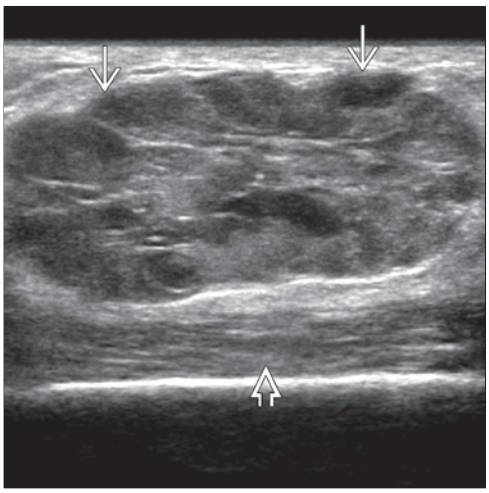


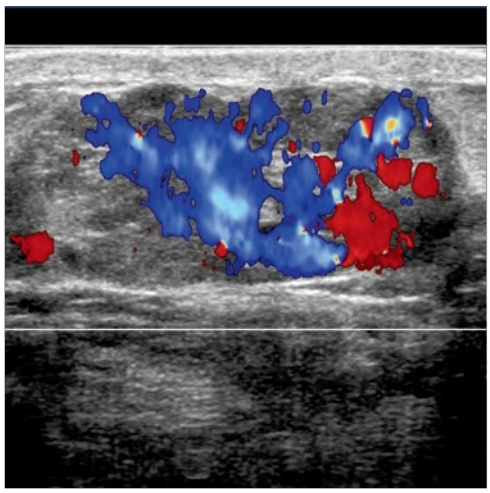


(Left) *Transverse color Doppler US of the same lesion as previous image shows venous-like color signal within some of the dilated vascular spaces* ➔. *Flow in some other vascular spaces is too slow* ➔ *to be detected.* ***(Right)*** *Longitudinal color Doppler ultrasound in a child shows a subcutaneous mass containing cavernous-type vessels* ➔ *filled with relatively stationary blood and fluid levels* ➔. *This is consistent with a cavernous-type venous vascular malformation. Only very little color flow* ➔ *is detected.*

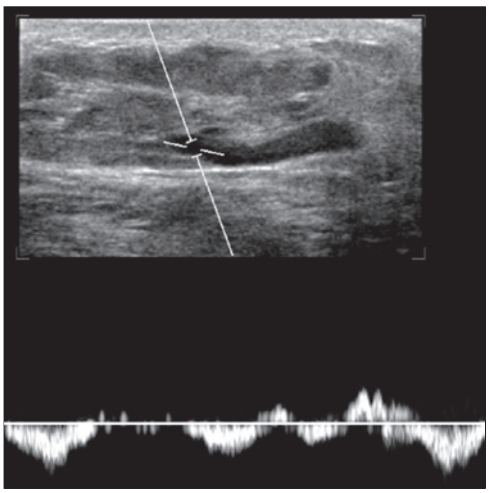
VASCULAR ANOMALY

(Left) *Longitudinal ultrasound of a 71-year-old patient with a long history of forearm swelling & recently increased in size shows a well-defined subcutaneous lobulated mass lesion ➔ without subfascial extension. The muscle layer ➔ is intact.* ***(Right)*** *Longitudinal color Doppler ultrasound of the same lesion shows the presence of ~ 50% mainly venous-type vascular channels & 50% supporting connective tissue stromal component. Change in the size of a vascular malformation may be due to altered hemodynamics secondary to thrombosis.*



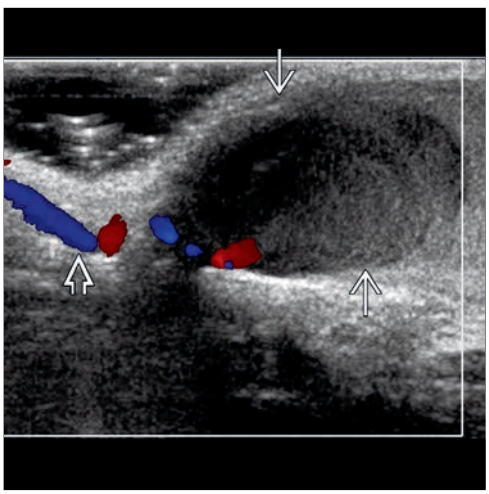


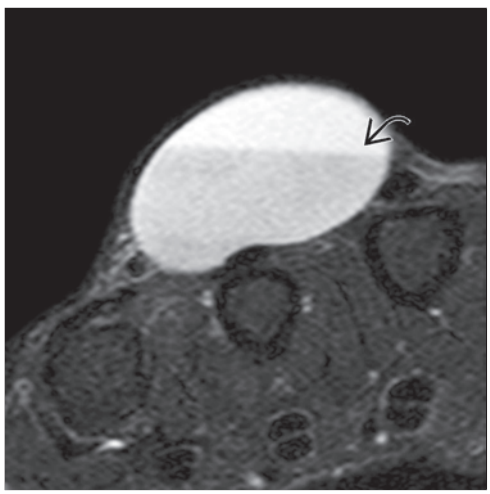
(Left) *Longitudinal spectral Doppler analysis of the same lesion as previous image shows a large venous vascular channel supplying the lesion. Features are indicative of a venous vascular malformation. This was confirmed by histology.* ***(Right)*** *Clinical photograph from a 41-year-old man shows a mass overlying the 4th metacarpophalangeal joint region with bluish discoloration and telangiectasia of the overlying skin.*

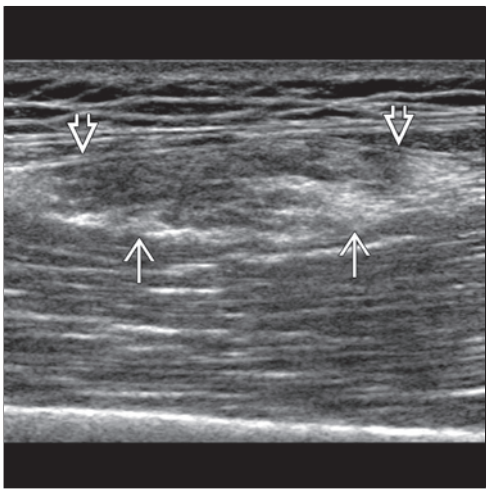


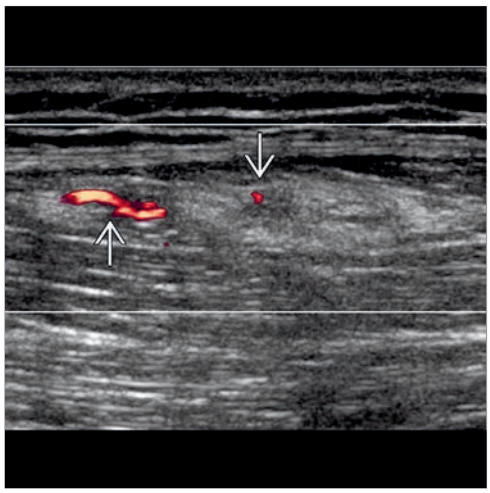


(Left) *Longitudinal color Doppler ultrasound of the same lesion shows a cystic mass ➔ filled with concentric layers of blood and with a distal arterial supply ➔. No fluid level is evident.* ***(Right)*** *Axial T2WI FS MR of the same lesion shows a T2-hyperintense mass with a fluid-fluid level ➔, indicative of a cavernous-type slow-flow venous vascular malformation. This was confirmed at histology. This case illustrates the complimentary nature of ultrasound and MR.*

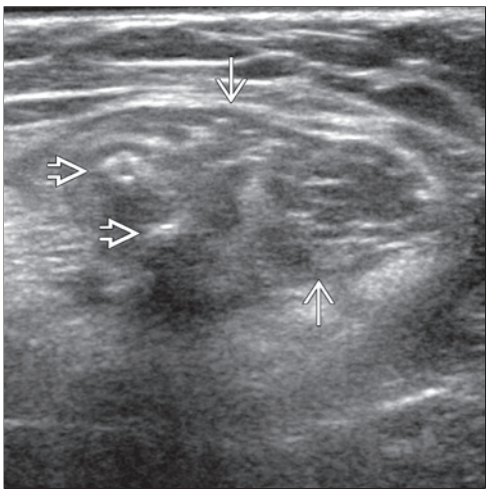


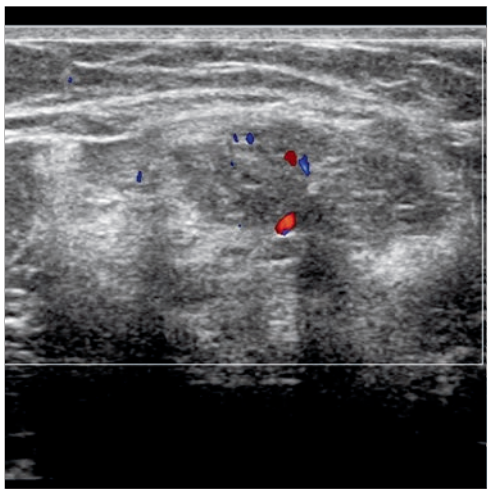






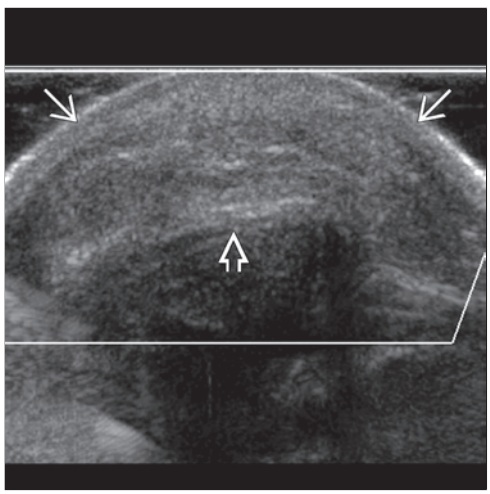
(Left) *Longitudinal US of an adult woman shows a fusiform-shaped, heterogeneous, hyperechoic, vascular malformation within the vastus lateralis muscle. The mass lies just deep to the investing fascia. **(Right)** Color Doppler US of the same lesion shows small vascular channels within the mass with venous-type flow. Follow-up ultrasound 6 months later showed no change in appearance. This lesion is consistent with a low-flow venous-capillary type vascular malformation.*





(Left) *Transverse ultrasound of a 37-year-old man shows a heterogeneous intramuscular mass lesion in the forearm. There are intralesional calcifications representing phleboliths with mild posterior acoustic shadowing. **(Right)** Transverse color Doppler ultrasound of the same lesion shows that the mass is mainly composed of stroma (± microscopic vasculature too small to be resolved). Despite the lack of color flow, the appearances are still consistent with a slow-flow venous or capillary-venous malformation.*

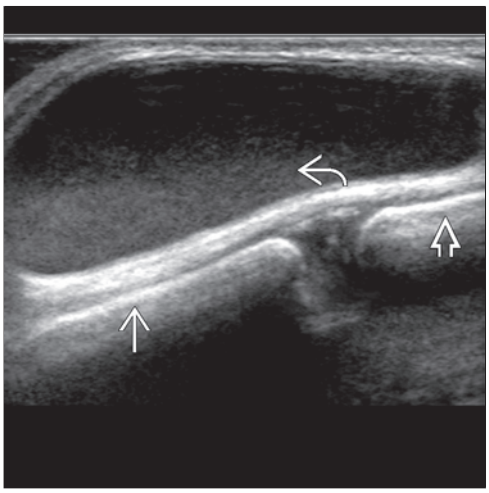


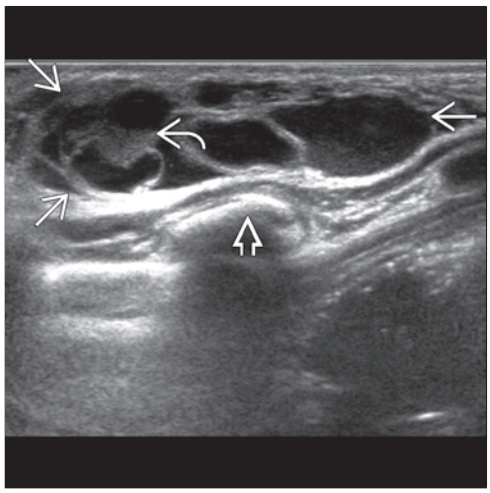


(Left) *Clinical photograph of a 10-year-old boy shows a soft tissue swelling with bluish skin discoloration on the anteromedial aspect of the knee. **(Right)** Transverse color Doppler ultrasound of the same lesion shows an echogenic mass without detectable intrinsic vascularity superficial to the patella. In this clinical context, the features are highly suggestive of a hemangioma or slow-flow capillary-type vascular malformation. Subsequent pathology revealed a verrucous hemangioma.*

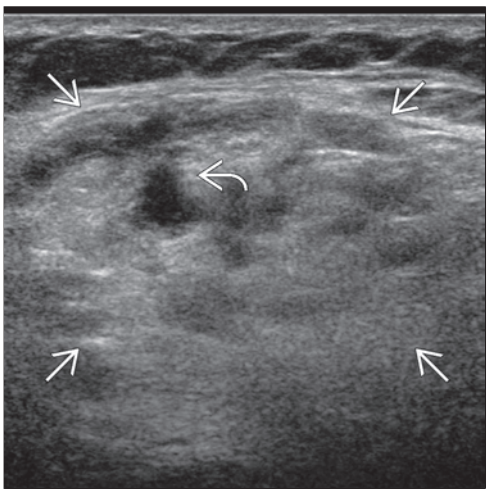
VASCULAR ANOMALY

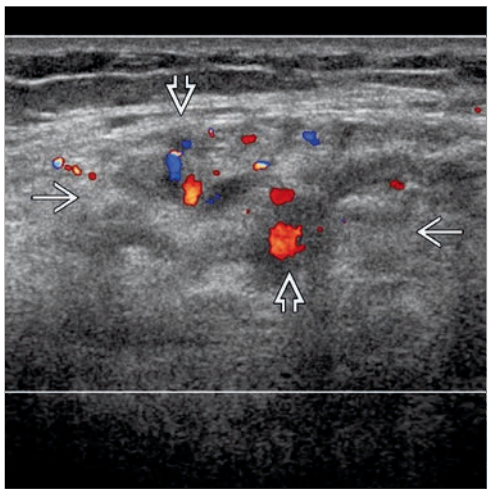
(Left) *Longitudinal US in a young boy shows a well-defined unioculated cystic lesion overlying sternum and manubrium. There was no detectable color signal. Cystic contents are mildly echogenic. Appearances are consistent with a unilocular lymphatic malformation.* ***(Right)*** *Infant chest wall shows a multicystic subcutaneous lesion overlying a rib. Some cysts contain fine echogenic material. Color Doppler revealed no flow. Appearances are consistent with multiloculated lymphatic malformation.*



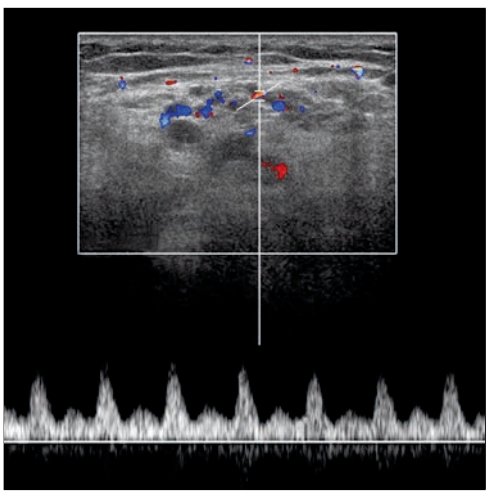


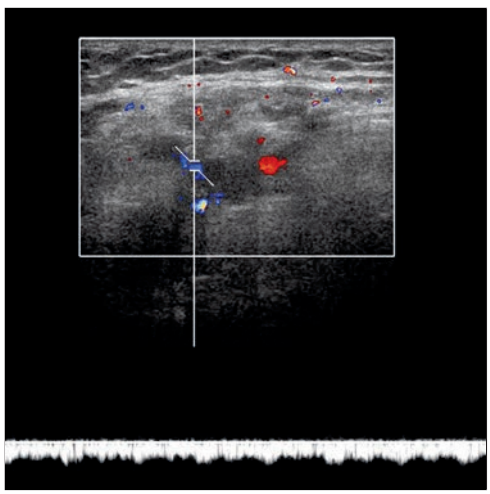
(Left) *Transverse ultrasound of a 31-year-old man with a 10-year history of leg swelling shows a large, ill-defined mass within the lateral belly of the gastrocnemius muscle containing some apparent dilated vascular channels.* ***(Right)*** *Color Doppler ultrasound of the same lesion shows that the mass is composed of a large amount of stroma with relatively little detectable vasculature.*

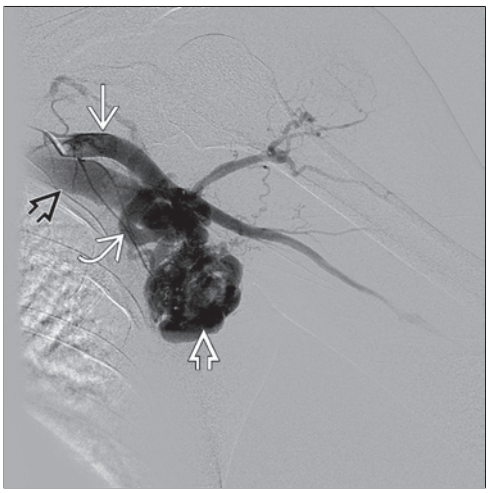


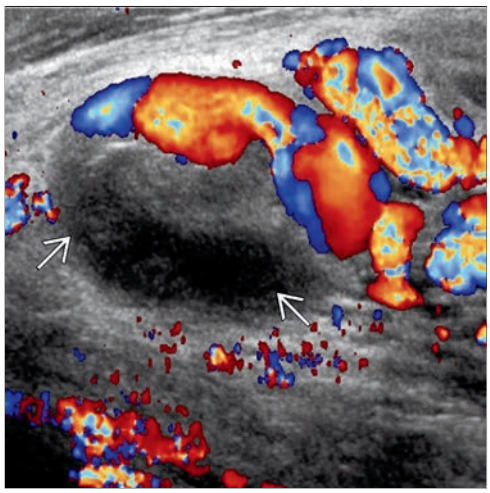


(Left) *Transverse pulsed Doppler ultrasound of the same lesion as previous image shows the presence of some arterial vascular flow within the lesion.* ***(Right)*** *Transverse pulsed Doppler ultrasound also shows the presence of venous vascular flow within the lesion. Most of the vessels were venous in type. Overall appearances are consistent with a slow-flow venous vascular malformation. Venous vascular malformations do have some arterial flow, but it is not the dominant feature.*

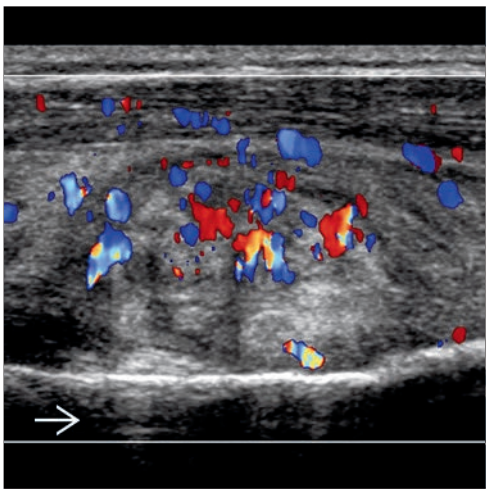


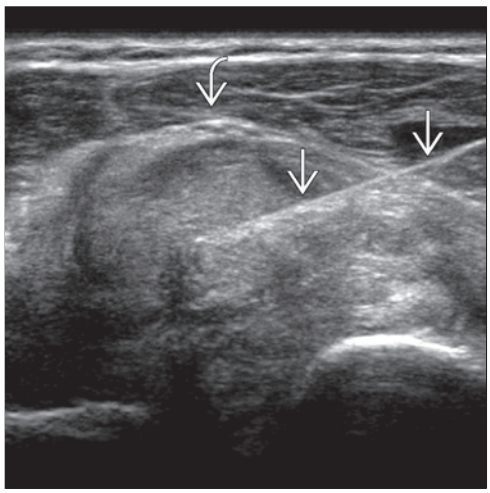




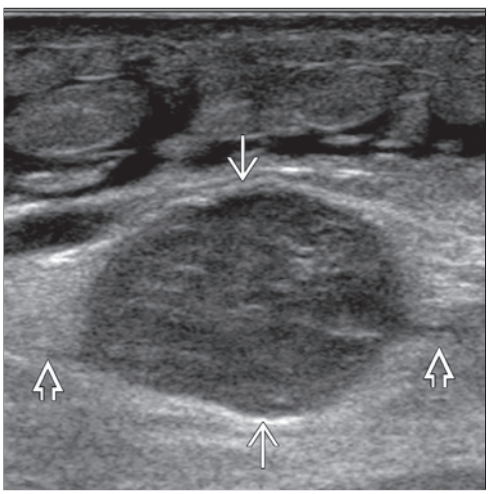


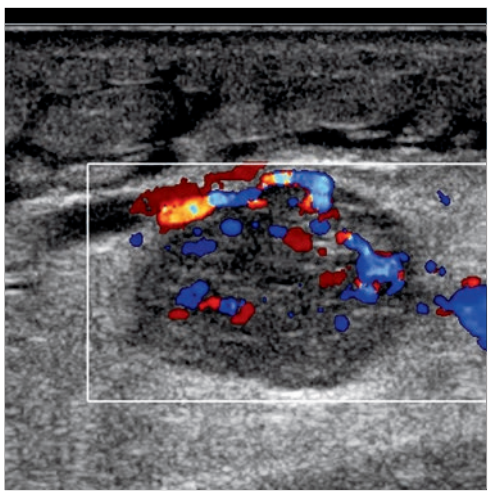
(Left) *Selective DSA of the subclavian artery shows an arteriovenous malformation with feeding arteries from the axillary* ➔ *and medial circumflex humeral arteries* ➔ *and with early venous drainage into the subclavian vein* ➔. *Note the lesion nidus* ➔. *Angiography is more helpful in high-flow than slow-flow vascular malformations.* ***(Right)*** *Transverse color Doppler ultrasound of the same arteriovenous malformation shows high flow around the partially thrombosed nidus* ➔.





(Left) *Longitudinal color Doppler ultrasound of a 40-year-old man shows a subfascial hypervascular heterogeneous mass abutting the radius* ➔. *As the clinical duration of this mass was only a few months, there was concern about sarcoma. The ultrasound appearances were not distinct enough to exclude this possibility.* ***(Right)*** *Transverse ultrasound during ultrasound-guided percutaneous biopsy shows the biopsy needle* ➔ *centered within the mass* ➔. *Histology revealed a venous vascular malformation.*





(Left) *Longitudinal ultrasound of a 76-year-old man shows a well-defined hypoechoic mass* ➔ *in the leg. Linear structures* ➔ *at the proximal and distal portions of the mass were suspected to be entering and exiting small subcutaneous nerves.* ***(Right)*** *Longitudinal color Doppler ultrasound of the same lesion shows moderate internal vascularity. An ultrasound diagnosis of a nerve sheath tumor arising from a small peripheral nerve was made, but histology subsequently revealed a vascular malformation.*

FOREIGN BODY AND INJECTION GRANULOMAS

Key Facts

Terminology

- Foreign body granuloma: Retention of penetrating or iatrogenic foreign body within tissues
- Injection granuloma: Localized tissue reaction to material injected into tissues

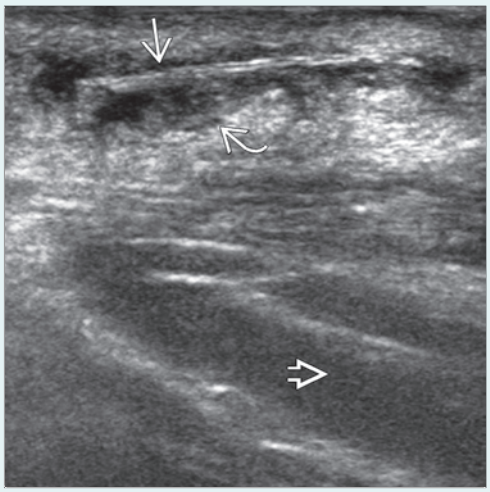
Imaging

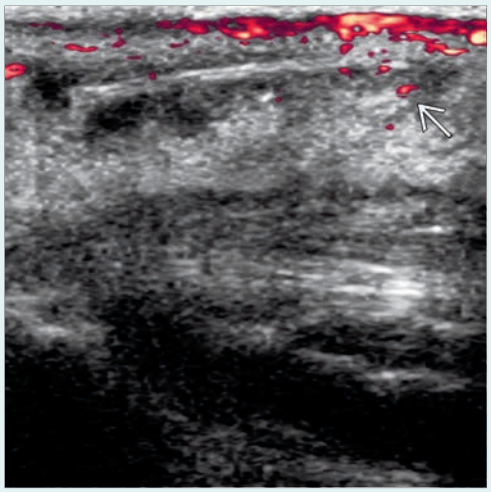
- Ultrasound: Modality of choice to detect radiolucent foreign bodies and diagnose injection granulomas
- **Foreign body granuloma**: Nearly 100% are detectable on ultrasound
  - Reflectivity of some objects (wood, metal, glass, plastic) exceeds that of others (bamboo)
  - Align probe as parallel to foreign body as possible; foreign body may be located some distance from entry wound
  - Echogenic foreign body ± posterior artifact (reverberation/"comet tail" artifact or posterior shadowing)
  - ± hypoechoic rim of inflammatory tissue, granulation tissue, or fibrosis
  - False-positive ultrasound with gas or calcification in soft tissues; correlate with radiographs if necessary
  - Repeat ultrasound in 2-10 days if clinical history is suspicious and ultrasound findings are negative or equivocal
- **Injection granuloma**: Focal hypoechoic subcutaneous mass with variable calcification and posterior acoustic shadowing
  - Especially in buttock and lateral aspect of arm

Clinical Issues

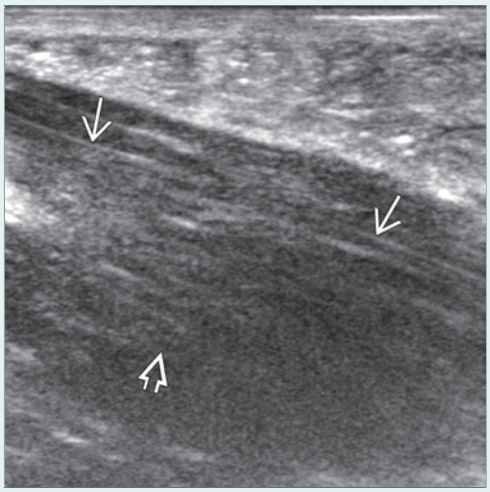
- Almost 90% of foreign bodies can be successfully removed using ultrasound guidance
- Hypoechoic rim can be breached by local anesthetic dissection or blunt forceps dissection

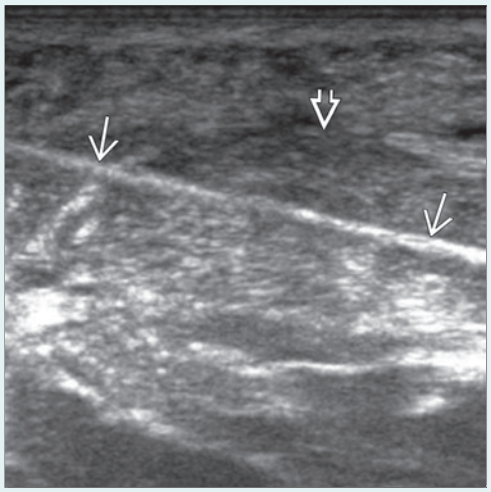
(Left) *Oblique ultrasound shows an echogenic wooden splinter in the subcutaneous region of the hand 7 days after a penetrating skin injury. A rim of hypoechoic granulation tissue surrounds the wood splinter. The thenar muscle is shown.* ***(Right)*** *Oblique color Doppler ultrasound of the same patient shows moderate hypervascularity in the adjacent subcutaneous and subdermal tissues. The wooden foreign body was removed under ultrasound guidance.*





(Left) *Oblique ultrasound shows a barely visible bamboo splinter within the edematous thenar muscle 1 day after a penetrating injury.* ***(Right)*** *Oblique ultrasound of the same area 4 days later shows that the bamboo splinter is now clearly visible as an echogenic foreign body. The thenar musculature is also less hypoechoic than previously. Follow-up ultrasound is particularly useful for suspected organic foreign bodies not visible on initial ultrasound examination.*





FOREIGN BODY AND INJECTION GRANULOMAS

TERMINOLOGY

Abbreviations
- Foreign body-type granuloma (FBG)
- Injection granuloma (IG)

Definitions
- FBG: Retention of penetrating or iatrogenic foreign body (FB) within tissues with resultant granulomatous reaction
- IG: Localized tissue reaction to material injected into tissues

IMAGING

General Features
- Best diagnostic clue
  - FBG: Echogenic material ± with posterior artifact ± hyperemic hypoechoic rim
  - IG: Localized hypoechoic swelling of subcutaneous tissues → ill-defined mass with peripheral hyperemia → well-defined mass ± calcification
- Location
  - FBG: Subcutaneous tissues >> deep tissues
    - Hands and wrists > feet
  - IG: Subcutaneous tissue, particularly superolateral aspect of gluteal region and lateral aspect of proximal arm
- Size
  - FBG: Usually small (1-3 cm) but can be large (≥ 10 cm)
    - Dependent on size of FB
  - IG: Usually small (2-5 cm)
    - Dependent on amount and dispersion of injected material
- Morphology
  - FBG: Depends on size and shape of FB and inflammatory response
    - Wood (45%), glass (25%), needle (10%), metal (10%), and others (e.g., grit, fish fin, pencil lead) (10%)
  - IG: Firm to hard subcutaneous nodule

Radiographic Findings
- FBG: Detects radiopaque FBs
  - ≤ 15% wood FBs are radiopaque
  - Limited information on exact location of FB and associated soft tissue response
- IG: ± calcified subcutaneous mass

CT Findings
- NECT
  - Foreign body granuloma
    - Typically seen as hyperdense object with variable surrounding inflammation or fibrosis
    - Wood may appear hypodense and simulate air
  - IG: Well-defined subcutaneous mass
    - ± lobulated or rim calcification (often dense)

MR Findings
- Less accurate than ultrasound at detecting FBs
  - Good visualization of inflammatory response

Ultrasonographic Findings
- Foreign body granuloma
  - Echogenic object ± posterior artifact (reverberation/"comet tail" artifact or posterior shadowing)
  - Echogenicity is dependent on acoustic impedance between retained FB and surrounding tissue
    - Reflectivity of some objects (wood, metal, glass, plastic) exceeds that of others (bamboo)
    - Reflectivity also dependent on smoothness of FB and alignment to ultrasound beam
  - ± hypoechoic halo of inflammatory tissue, granulation tissue, or fibrosis
    - Presence of halo depends on intensity of inflammatory response and duration of retention of FB
      - May be apparent within 24 hours of retention
    - Improves sensitivity and specificity of ultrasound detection
    - Variable hyperemia of hypoechoic rim or hab
  - ± sinus tract to FB
    - Either along tract of penetrating FB or developing de novo from retained FB
- Injection granuloma
  - Focal swelling and disruption of subcutaneous fat
    - Similar to early stages of fat necrosis
    - ± small areas of liquefaction
    - ± mild peripheral hyperemia
  - Swelling may progress to ill- or well-defined hypoechoic mass
    - ± mild peripheral hyperemia
    - ± dense calcification
      - Limits visibility of deep margin of mass

Nuclear Medicine Findings
- IG may accumulate tracer on FDG PET imaging
  - False-positive for subcutaneous metastatic deposit

Imaging Recommendations
- Best imaging tool
  - Ultrasound: Modality of choice to detect radiolucent FBs and diagnose IGs
    - Sensitivity and specificity > 90% for radiolucent FB detection
- Protocol advice
  - Foreign body granuloma
    - First, check with patient regarding type and size of FB, direction of implantation, and likelihood of FB retention
    - Align probe as parallel to FB as possible
    - Examine beyond entry wound
    - FB may be located some distance from entry wound
      - For example, hand entry wound may give rise to FB in distal forearm
    - Note size, shape, location, and orientation of FB
      - Relate size and shape to recalled FB
    - Assess presence, thickness, and vascularity of hypoechoic rim
    - Look for associated complications (soft tissue infection, neurovascular or tendon injury)
    - False-positive ultrasound can occur due to gas or calcification in soft tissues
      - Correlate with radiographs (calcification is radiopaque)

FOREIGN BODY AND INJECTION GRANULOMAS

- Repeat ultrasound in 2-10 days if clinical history is suspicious and ultrasound findings are negative or equivocal
- Injection granuloma
  - Assess location, size, and margination of granuloma
  - Assess vascularity and present of calcification
  - Fine-needle aspiration for cytology, biopsy, and additional imaging is generally not necessary

DIFFERENTIAL DIAGNOSIS

Subcutaneous Fat Necrosis
- Localized swelling and ↑ echogenicity and disruption of subcutaneous fat
  - No linear echogenic material within mass
- ± history of prior blunt trauma

Subcutaneous Fibroma
- Hypoechoic well-defined subcutaneous nodule
  - No linear echogenic material within mass
- No history of penetrating trauma or injection

Subcutaneous Metastasis
- Hypoechoic vascular nodule
  - No linear echogenic material within mass
- No history of penetrating trauma or injection
- Usually known disseminated malignancy

PATHOLOGY

General Features
- Etiology
  - Foreign body granuloma
    - Penetrating FB (wood, glass, metal sliver, bamboo, etc.)
    - Retained FB (gauze, cotton swab, etc.)
  - Injection granuloma
    - Injection of drug into subcutaneous fat
    - Many intended intramuscular injections occur instead in subcutaneous tissue
      - Granulomas are much less frequent with intramuscular injection
    - Tissue reaction is dependent on site, composition, and amount of injected material

Gross Pathologic & Surgical Features
- FBG: FB with variable rim of inflammatory or fibrous tissue
- IG: Tissue necrosis with mass composed of inflammatory or fibrous tissue

Microscopic Features
- Injection granuloma
  - Necrosis of fat cells
  - Dense fibrous tissue reaction with inflammation
  - ± FB giant cells
    - Inflammation may persist > 1 year after injection

CLINICAL ISSUES

Presentation
- Most common signs/symptoms
  - Foreign body granuloma
    - History of penetrating injury
    - Palpable mass, initially tender but becoming less tender over ensuring weeks
  - Injection granuloma
    - History of injection
    - Tender area → palpable mass
- Other signs/symptoms
  - Original trauma or injection may be forgotten
    - May present as unexplained mass

Demographics
- Age
  - FBG: Young or middle-aged patients
  - IG: Elderly patients

Natural History & Prognosis
- Foreign body granuloma
  - Inert material leads to nontender mass
  - Non-inert material leads to continuing tissue reaction, which persists as tender mass
    - Chronic Inflammatory reaction ± sinus tract to skin
  - Injection granuloma
    - Mass becomes less tender, smaller, and harder
    - Usually persists as small hard nodule

Treatment
- Foreign body granuloma
  - Percutaneous ultrasound-guided removal
    - Almost 90% of FB can be successfully removed
    - Superficial FB: Localization → 2-3 mm incision → removal with needle or forceps under direct vision
    - Deep FB: Localization → 2-3 mm incision → blunt dissection with forceps and removal using ultrasound guidance
      - Removal along long axis of FB minimizes likelihood of FB breaking during retrieval
      - Standard mosquito forceps or crocodile forceps
      - Use transducer pressure to fix FB during approach with forceps
      - Hard materials are generally easier to remove (positive feedback on contact)
  - Cutaneous or needle location → surgical excision
- Injection granuloma
  - Treatment is rarely necessary

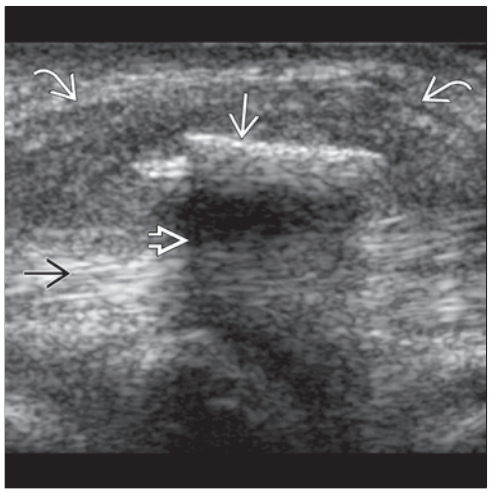
DIAGNOSTIC CHECKLIST

Consider
- Routine use of ultrasound has dramatically ↑ detection rate of soft tissue FBs and ↓ number of unnecessary operations
- Ultrasound appearances of IGs are specific enough not to warrant further investigation
- Be careful about diagnosing small thin (e.g., submillimeter) FBs on ultrasound
  - Fine echogenic lines masquerading as thin FBs can be seen in almost any tissue
    - Look for associated FB reaction

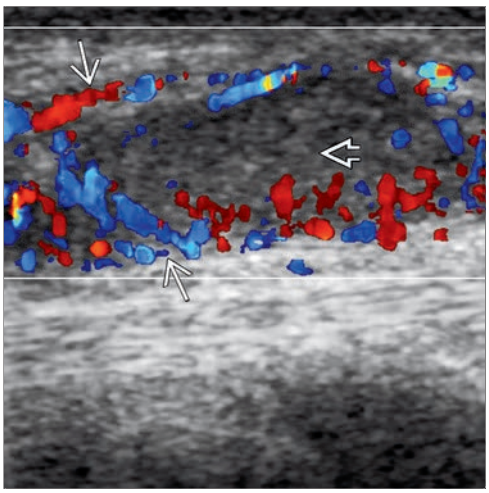
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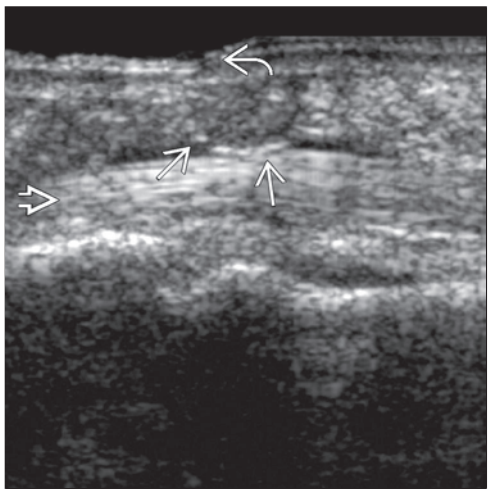
1. Bradley M: Image-guided soft-tissue foreign body extraction - success and pitfalls. Clin Radiol. 67(6):531-4, 2012



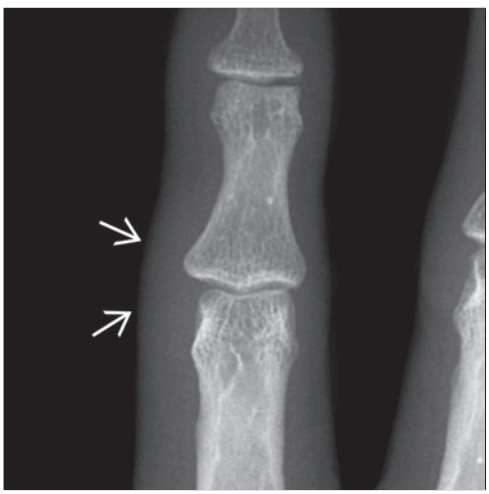


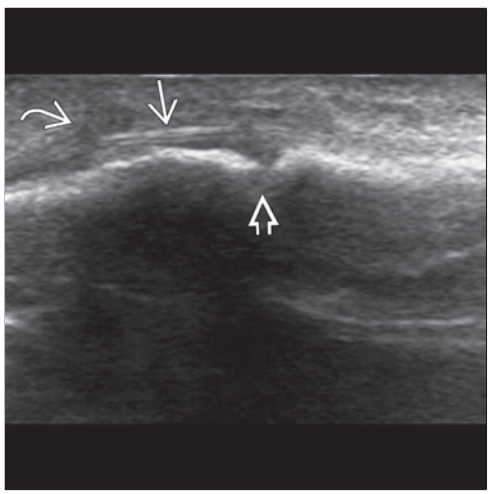
(Left) *Clinical photograph shows an almost healed entry site of a wood splinter in a patient who presented with a palpable mass at the midpalm region 4 weeks following initial injury.* ***(Right)*** *Oblique ultrasound of the palm in the same patient shows the wood splinter with posterior acoustic shadowing on the volar aspect of the carpus, superficial to a flexor tendon. A thick rim of reparative granulation tissue surrounds the foreign body.*





(Left) *Oblique ultrasound of the same patient shows marked hypervascularity of the surrounding hypoechoic rim, compatible with immature granulation tissue.* ***(Right)*** *Longitudinal ultrasound of the palm shows a curvilinear echogenic rim just superficial to a flexor tendon. This echogenic rim moved with transducer pressure and was due to air, not a glass foreign body. The cutaneous wound is shown. Follow-up ultrasound 2 days later showed no foreign body.*

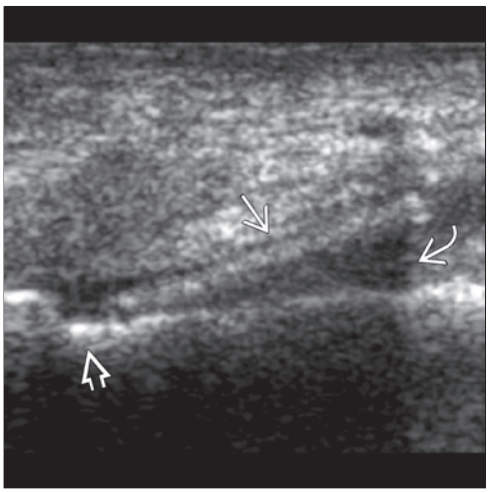


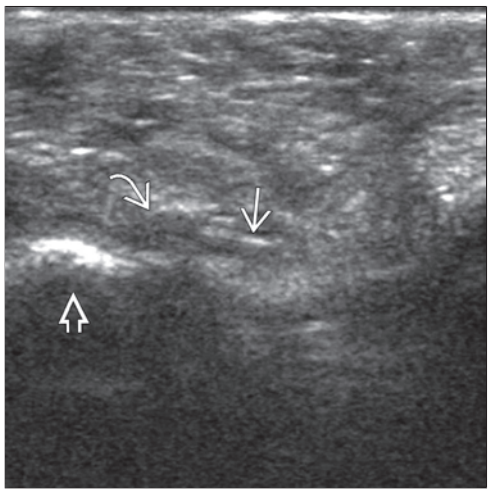


(Left) *Anteroposterior radiograph of a patient with suspected wood splinter of the index finger shows mild focal soft issue swelling on the radial side of the proximal interphalangeal joint. No visible radiopaque foreign body is seen.* ***(Right)*** *Longitudinal ultrasound of the same patient shows an echogenic wood splinter on the radial aspect of the proximal interphalangeal joint with a thin hypoechoic halo of granulation tissue.*

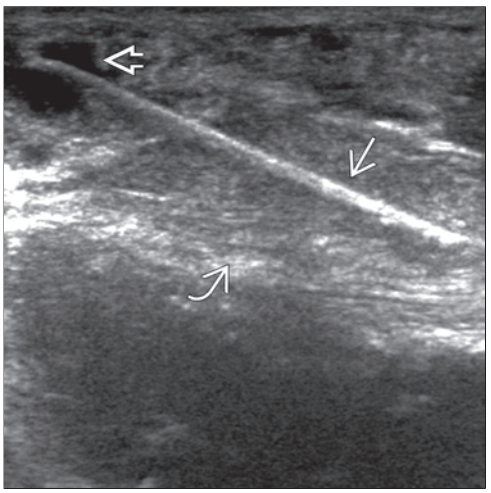
FOREIGN BODY AND INJECTION GRANULOMAS

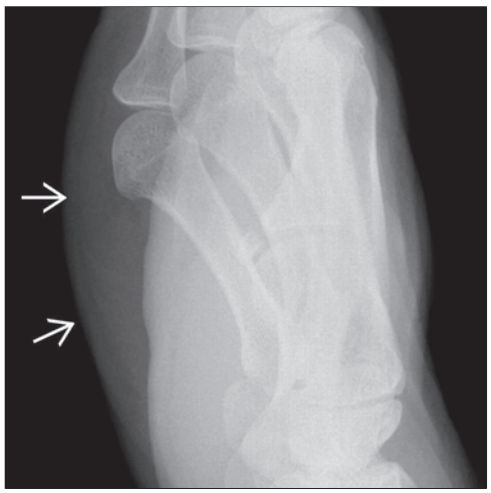
(Left) *Longitudinal ultrasound shows a bamboo splinter with surrounding granulating tissue and acoustic shadowing on the volar aspect of the 3rd metacarpal bone.* ***(Right)*** *Oblique ultrasound shows a small wood splinter deep on the volar aspect of the hand. A thin halo of granulation tissue is present making the splinter more conspicuous. Note the adjacent metacarpal head.*



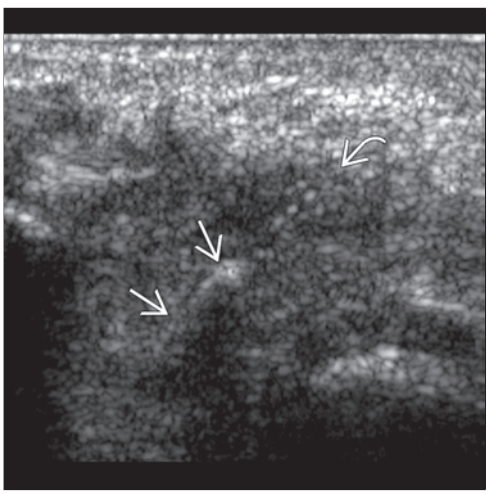


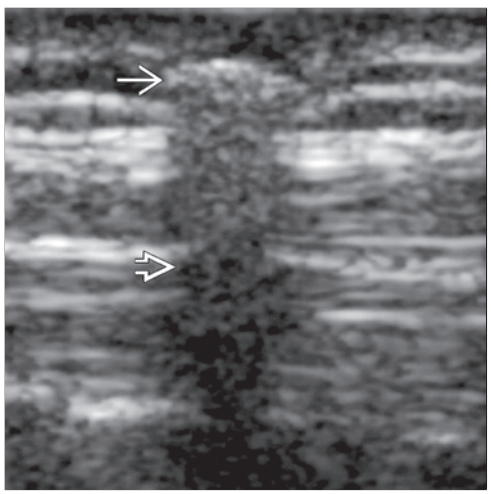
(Left) *Oblique ultrasound shows a wood splinter within the thenar muscle. There is a small hypoechoic area (most likely due to a small fluid collection) at the proximal tip of the splinter.* ***(Right)*** *Lateral radiograph of the same patient shows only mild soft tissue swelling in the thenar region. No visible radiopaque foreign body is seen.*

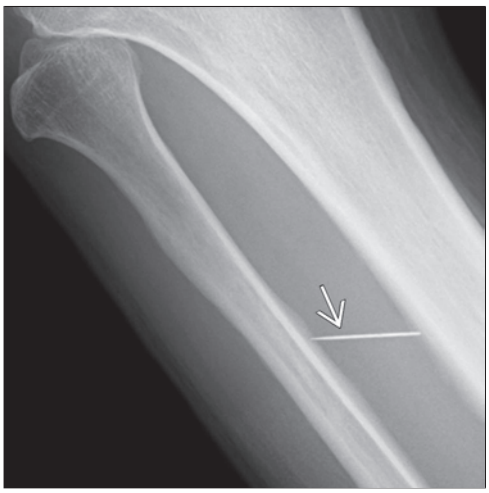


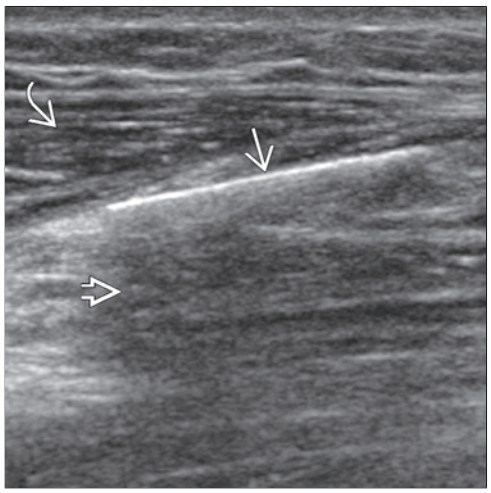


(Left) *Oblique ultrasound on the volar aspect of the hand shows a thin curvilinear glass fragment deep in the palm with surrounding hypoechoic edematous inflammatory tissue. Follow-up ultrasound about 1-2 weeks later would be helpful to reassess when the inflammatory response has settled.* ***(Right)*** *Transverse ultrasound shows a superficially located metallic foreign body within the subcutaneous tissues of the leg. There is strong posterior acoustic shadowing.*

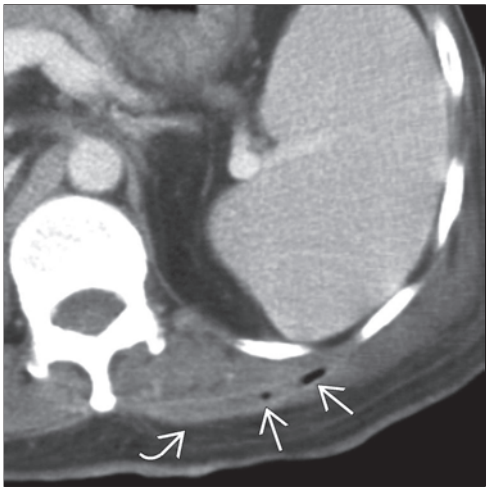


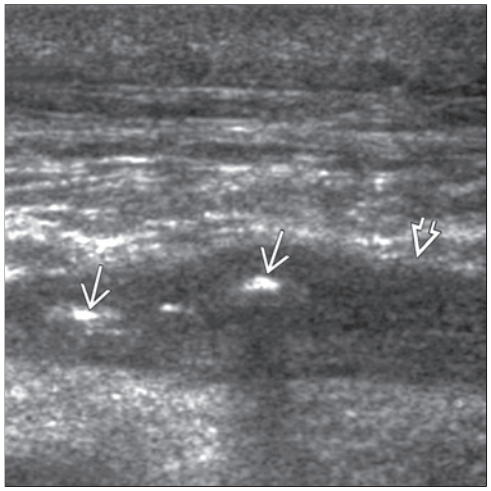




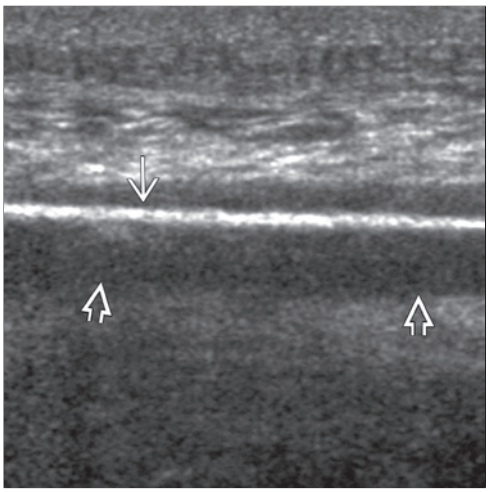


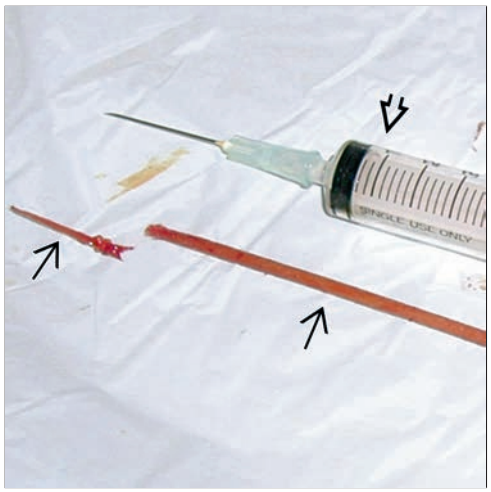
(Left) *Anteroposterior radiograph shows a metallic foreign body (needle) in the proximal aspect of the leg several hours after a penetrating injury.* ***(Right)*** *Oblique ultrasound of the same patient shows how the echogenic needle is located within the superficial fibers of the soleus muscle. There is mild posterior acoustic shadowing. The overlying gastrocnemius muscle is normal. Ultrasound allows precise foreign body localization. This FB was removed under US guidance.*





(Left) *Transverse CECT in a patient with penetrating chest trauma shows 2 radiolucent wood splinters in the posterior chest wall with a medium-sized isodense halo of rim-enhancing granulation tissue.* ***(Right)*** *Oblique ultrasound at the same location (same patient) shows the 2 echogenic wood splinters with a thick hypoechoic halo of fibrous tissue. Wood foreign bodies can mimic air, being hypodense on CT and echogenic on ultrasound.*

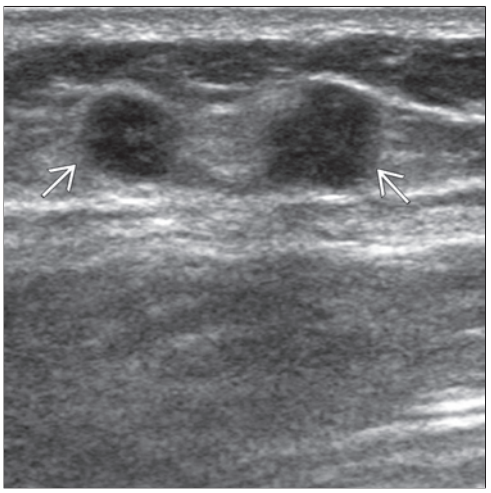


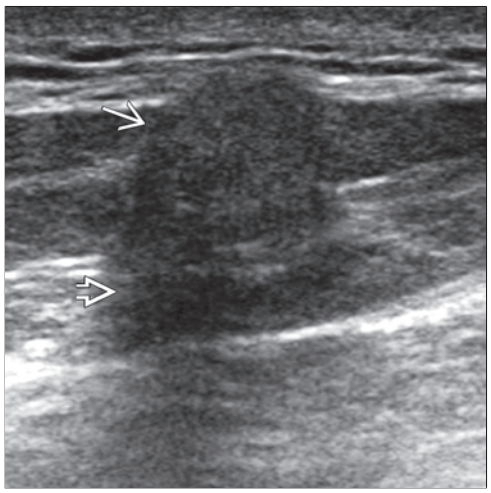


(Left) *Oblique ultrasound of the same area (same patient) clearly shows the echogenic wood splinter against a hypoechoic halo of granulomatous-type tissue.* ***(Right)*** *Clinical photograph of the same patient shows the 2 wood splinters removed using forceps and blunt dissection under ultrasound guidance and local anesthesia. A rim of granulation tissue does not preclude image-guided removal as it can be breached by local anesthetic dissection or blunt dissection.*

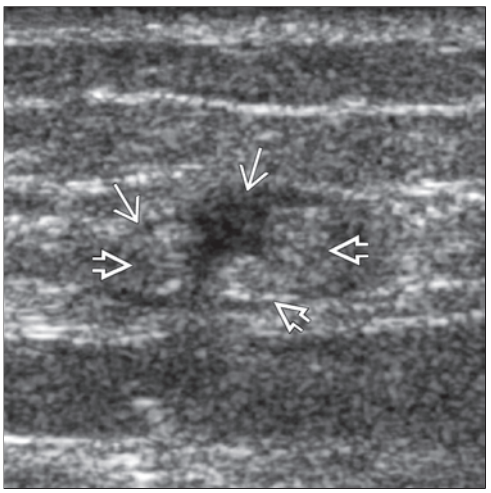
FOREIGN BODY AND INJECTION GRANULOMAS

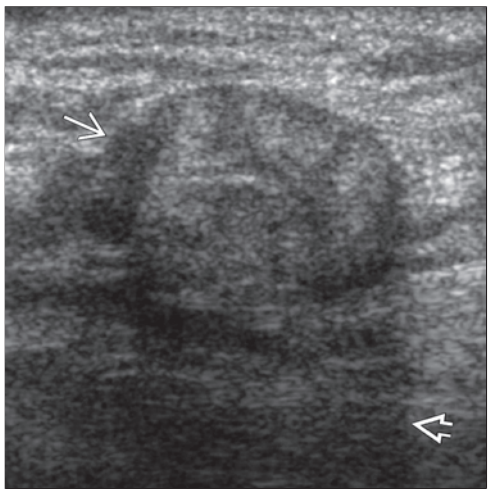
(Left) *Transverse ultrasound shows 2 small injection granulomas in the subcutaneous region of the forearm. There is no calcification of these granulomas.* ***(Right)*** *Transverse ultrasound shows a subcutaneous injection granuloma in the buttock region. There is mild to moderate posterior acoustic shadowing.*



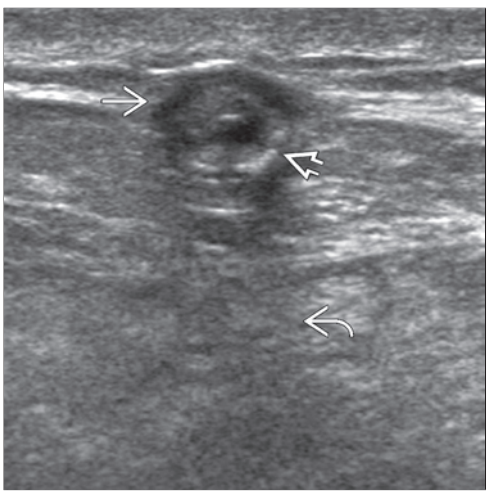


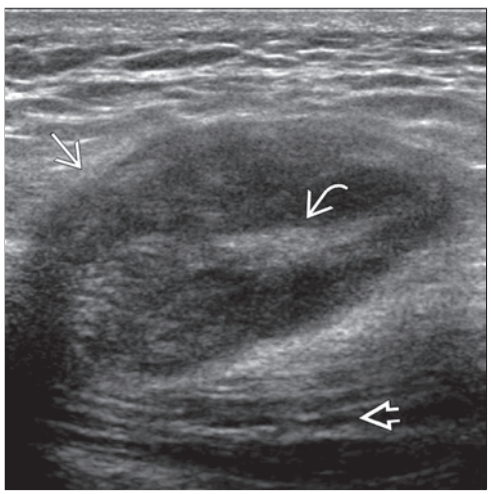
(Left) *Oblique ultrasound shows a subcutaneous injection granuloma in the buttock region. The granuloma is heterogeneous with a central hypoechoic area surrounded by hyperechoic tissue. This appearance is probably due to a combination of mature (hypoechoic) and immature (hyperechoic) granulation tissue.* ***(Right)*** *Transverse ultrasound of the buttock shows a large, mildly hypoechoic subcutaneous injection granuloma with moderate posterior acoustic shadowing.*

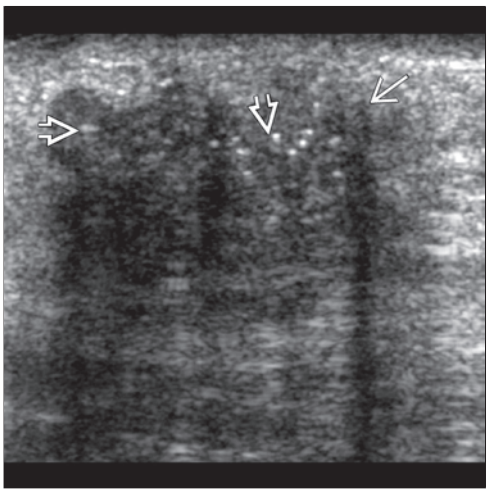


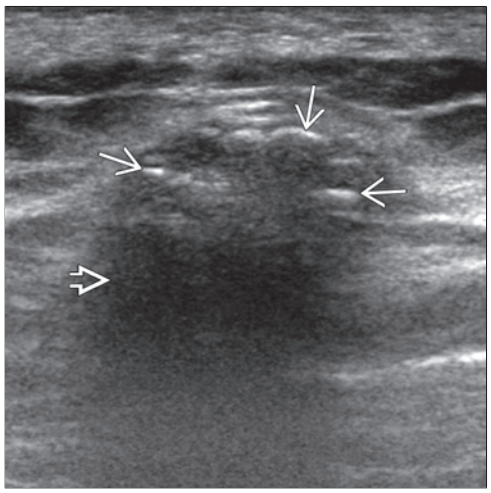


(Left) *Transverse ultrasound shows a small injection granuloma in the subcutaneous tissues of the buttock. Note the presence of early rim calcification and mild posterior acoustic shadowing.* ***(Right)*** *Transverse ultrasound shows a large injection granuloma in the deep subcutaneous tissue of the buttock. The granuloma is abutting the gluteus muscle. An echogenic band traverses the granuloma.*

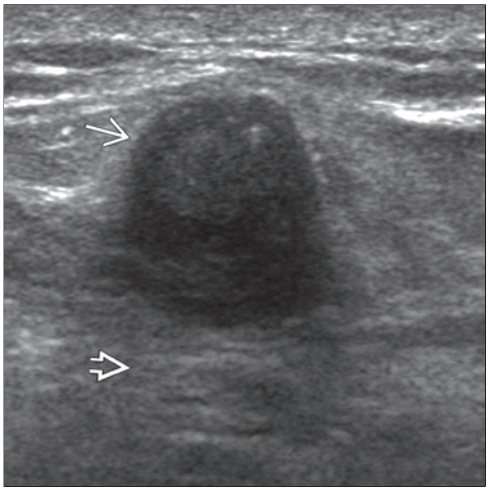


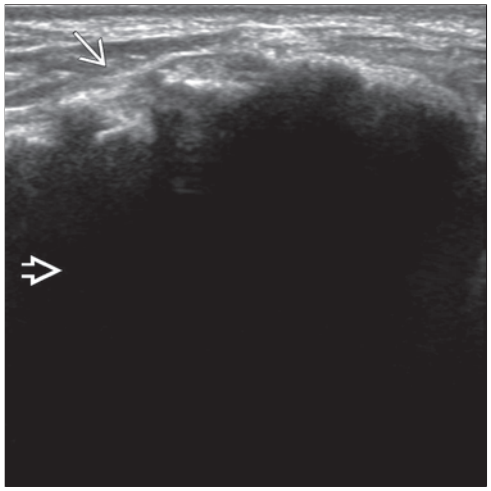




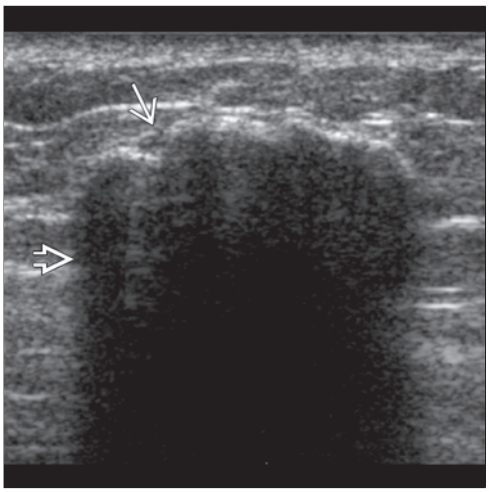


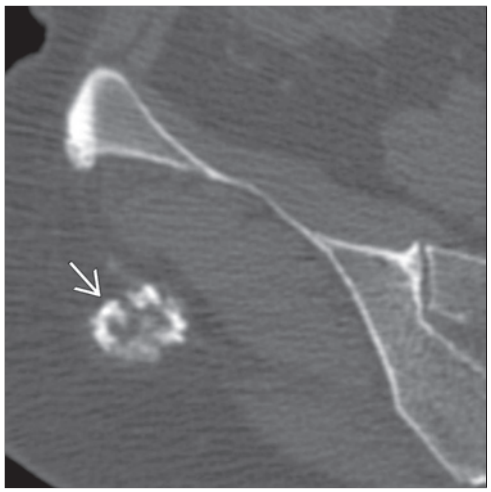
(Left) *Transverse ultrasound shows a large irregular injection granuloma ➔ in the subcutaneous region of the buttock. There are numerous small calcific foci ➔ within the injection granuloma.* ***(Right)*** *Transverse ultrasound shows an injection granuloma of the buttock with several medium-sized calcific foci ➔ and strong posterior acoustic shadowing ➔. Injection granulomas show either no hyperemia or only minimal hyperemia on color Doppler imaging (not shown).*





(Left) *Transverse ultrasound shows a very hypoechoic subcutaneous injection granuloma ➔ in the buttock region. This hypoechogenicity is most likely due to dense mature fibrosis rather than calcification as there is only minimal acoustic shadowing ➔.* ***(Right)*** *Transverse ultrasound shows a large, heavily calcified granuloma ➔ with very strong posterior acoustic shadowing ➔ completely obscuring the tissues deep to the granuloma.*





(Left) *Transverse ultrasound shows a large, heavily calcified subcutaneous granuloma ➔ of the buttock. There is severe acoustic shadowing ➔. The ultrasound appearances of injection granulomas are usually diagnostic, with no need for additional imaging.* ***(Right)*** *Axial NECT of the same patient shows the calcified granuloma ➔ in the deep subcutaneous region of the buttock. Granulomas are commonly seen as incidental findings in patients undergoing CT for unrelated reasons.*

LYMPH NODE ABNORMALITY

Key Facts

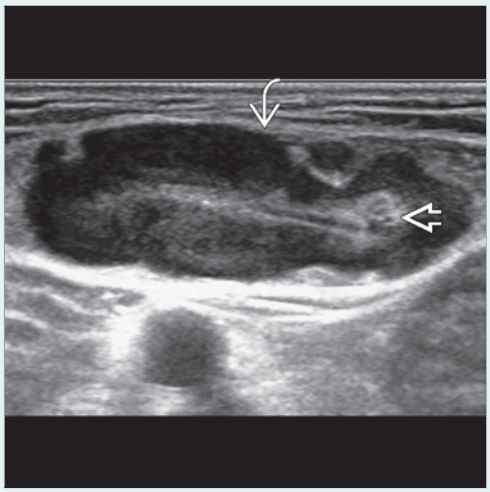
Imaging
- Ultrasound
  - Accurate at differentiating between benign and malignant nodes
  - More accurate than CT and MR provided that nodes are accessible to US assessment
  - Can guide FNA cytology or biopsy
  - Appearances vary depending on whether node is normal, reactive, metastatic, lymphomatous, or infected (TB or non-TB infection)
  - Important discriminatory criteria: Size, nodal configuration, border, internal architecture, and pattern of vascularity
  - Color Doppler to assess pattern of vascularity
  - Spectral analysis is not routinely helpful
  - Ultrasound-guided FNA for microbiological, cytological, or histological analysis

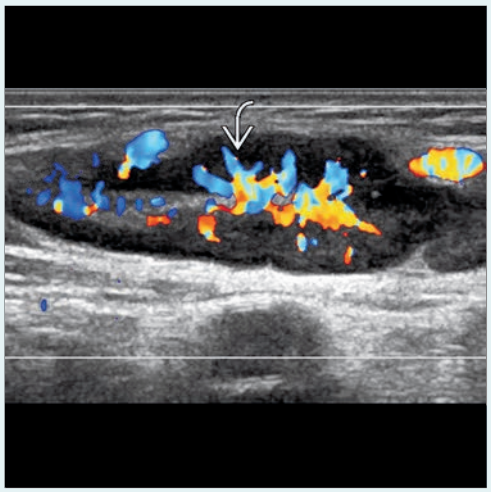
Top Differential Diagnoses
- Nerve sheath tumor
- Vascular leiomyoma
- Vascular anomaly

Clinical Issues
- Lymphadenitis: Very tender
- Reactive adenopathy: Mildly tender
- Metastatic, lymphomatous, and tuberculous nodes: Nontender

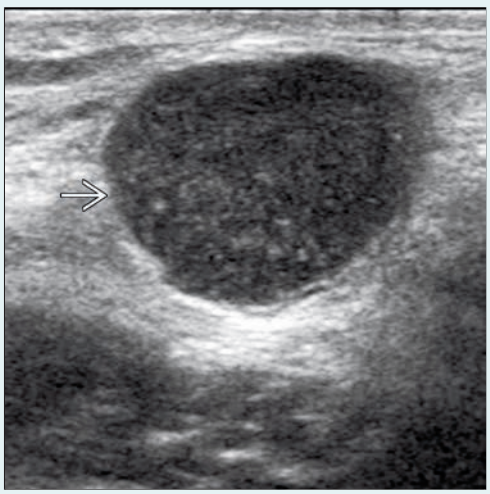
Diagnostic Checklist
- Ultrasound diagnosis should be formulated on relative strength of many ultrasound signs in conjunction with clinical presentation
  - Using this approach, ultrasound is accurate at determining presence and likely etiology of nodal pathology as well as need for FNA cytology

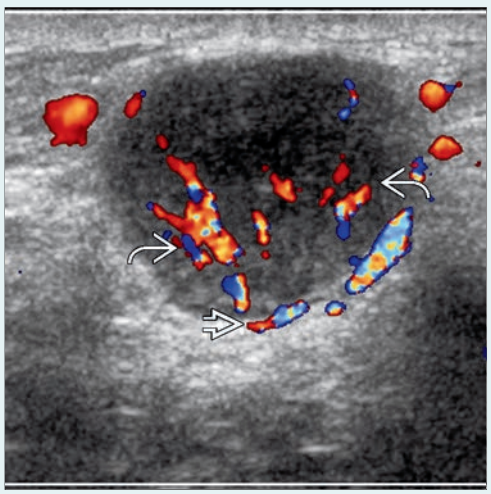
(Left) *Longitudinal ultrasound shows a reactive groin node in a patient with ipsilateral shin cellulitis. The lymph node is elliptical in shape with moderate irregular cortical thickening and a distinctive central echogenic fatty hilum.* ***(Right)*** *Longitudinal color Doppler ultrasound of the same lymph node shows a normal hilar vascular flow pattern with branching intranodal vessels extending from the hilum into the hypoechoic cortical parenchyma.*





(Left) *Longitudinal ultrasound shows a metastatic groin node. The lymph node is roundish in shape and is diffusely hypoechoic with loss of the central echogenic fatty hilum.* ***(Right)*** *Longitudinal color Doppler ultrasound of the same lymph node shows a peripheral vascular flow pattern. There is loss of normal central hilar vascularity with a rather chaotic capsular and cortical parenchymal vascular pattern.*





LYMPH NODE ABNORMALITY

TERMINOLOGY

Synonyms
- Lymphadenopathy, adenopathy, lymph node enlargement, lymphadenitis

Definitions
- Reactive node
  - Enlargement of node in response to antigenic stimuli including infection and inflammation
    - "Reactive" implies benign etiology
- Metastatic node
  - Enlargement of node due to metastatic infiltration
- Lymphomatous node
  - Enlargement of node due to lymphoma infiltration
- Tuberculous node
  - Enlargement of node due to tuberculous infection
- Lymphadenitis
  - Enlargement of node due to bacterial or fungal infection

IMAGING

General Features
- Best diagnostic clue
  - Enlargement of lymph node with altered nodal architecture
- Location
  - Any sites along lymphatic drainage
  - Head and neck > groin > axillae
- Size
  - ~ 3 mm to > 10 cm
- Morphology
  - Elliptical, oval, or rounded nodes

CT Findings
- Reactive node: Central fatty hilum with hypoechoic peripheral cortex of variable thickness
- Malignant node: Solid soft tissue nodule with no identifiable fatty hilum
- ± intranodal cystic change, calcification, matting, or perinodal soft tissue inflammation
- Irregular border indicates extranodal spread

Ultrasonographic Findings
- Accurate at differentiating between benign and malignant nodes
  - Reasonably accurate at identifying other nodal pathologies
  - More accurate than CT and MR if nodes are accessible
  - Can guide fine-needle aspiration (FNA) cytology or biopsy
- Size is important, but only 1 of several discriminatory criteria used
- Nodal configuration, border, internal architecture, and pattern of vascularity are also important
- **Normal and reactive lymph nodes**
  - Normal node: Long axis < 8 mm
  - Reactive node: Long axis usually > 8 mm
  - Elliptical or ovoid in shape
    - Long- to short-axis length ratio > 2
  - Hypoechoic cortex compared with adjacent muscle
    - Variable cortical hyperplasia (thickening)
      - Leading to lobulated cortical hyperplasia
  - Normal echogenic fatty hilum
  - Hilar vascularity on color Doppler imaging
    - Central hilar vessels branch radially into cortical parenchyma of node
- **Metastatic lymph node**
  - Long axis > 8 mm
    - Some malignant nodes have long axes of only 6-8 mm
  - Rounded shape
    - Long- to short-axis length ratio < 2
  - Effacement or replacement of echogenic fatty hilum
  - Thickened hypoechoic cortex
  - Usually well-demarcated border
    - Irregular blurred contour suggests extranodal spread
  - ± punctate calcification depending on primary tumor
    - Calcification feature of chondroid, osteosarcoma metastases, papillary, and medullary thyroid carcinoma metastases
  - ± intranodal cystic change
    - Seen with squamous cell carcinoma and melanoma
  - ± matting of adjacent nodes
    - Seen in malignancy > TB > lymphoma
  - Peripheral capsular vascularity or mixed hilar and peripheral vascularity
    - Presence of peripheral vascularity only is highly suspicious of metastases
    - Chaotic rather than regular vascular pattern
    - Impedance values (resistive index, pulsatility index) of limited value due to large overlap with reactive values
- **Lymphomatous node**
  - Usually > 8 cm
    - Can be very large
  - Rounded in shape
    - Focal cortical thickening due to focal cortical infiltration
  - Usually sharp border without extracapsular spread
    - Unsharp border suggestive of extracapsular spread and aggressive disease
  - Loss of normal echogenic hilum (75%)
  - Usually very hypoechoic
    - Uniform cellular infiltration within node produces few interfaces → good acoustic transmission → posterior acoustic enhancement
  - Intranodal reticular pattern
    - Thin echogenic lines traversing hypoechoic node
      - Seen in lymphoma and malignancy
  - Calcification is rare; may be present after treatment
  - Cystic necrosis is uncommon
  - Mixed prominent hilar and peripheral vascularity
    - Peripheral vascularity alone is rare
  - Nodal size ↓ with treatment indicates good response
- **Tuberculous node**
  - Enlarged > 8 cm
  - Oval or rounded
  - Hypoechoic nodes with intranodal necrosis
    - Posterior acoustic enhancement
  - Matting of multiple nodes
  - Perinodal soft tissue inflammation (periadenitis)
  - Calcification
    - Seen following treatment, usually not seen in acute phase

- Variable vascular pattern
  - Preserved but displaced hilar vascularity (50%)
  - Absent hilar vascularity (19%)
    - Intranodal vessels obliterated by necrotizing granulomatous inflammation
    - Intranodal vessels obliterated by fibrosis and hyalinization in healing phase
  - Capsular vascularity (12%) from perinodal inflammation
- **Lymphadenitis**
  - Suppurative or nonsuppurative infection of lymph nodes
  - Enlarged node with preservation of nodal architecture, hyperemia, ± liquefaction and periadenitis

Imaging Recommendations

- Best imaging tool
  - High-resolution ultrasound
    - Nodes in neck, supraclavicular fossa, axilla, elbow, groin, and popliteal fossa are all accessible to examination by ultrasound
- Protocol advice
  - Grayscale to assess nodal size, shape, border, and internal architecture
    - For axillary nodes, sweep transducer along center and sides of axillary artery
      - Normal axillary nodes have large fatty hilum and thus are rather inconspicuous against axillary fat
    - Routinely examine external iliac nodes when examining inguinal nodes
      - Particularly large subcutaneous node in proximal medial thigh (Cloquet node) is normal finding
    - Normal elbow (epitrochlear) and popliteal fossa nodes are not routinely visible
  - Color Doppler to assess pattern of vascularity
    - Minimal transducer pressure ensures that vascularity is not effaced
    - Spectral analysis is not routinely helpful
  - Ultrasound-guided FNA to obtain microbiological, cytological, or histological diagnosis
    - Apply suction as needle is moved "to and fro" within node while simultaneously rotating needle between index finger and thumb to increase cutting effect

DIFFERENTIAL DIAGNOSIS

Nerve Sheath Tumor

- Thickened entering and exiting nerve
- No echogenic fatty hilum

Vascular Leiomyoma

- Peripheral converging vascularity
- No echogenic fatty hilum

Vascular Anomaly

- Irregular border
- Intrinsic vascular mesh

PATHOLOGY

General Features

- Etiology
  - Reactive node
    - Inflammation, infection, allergy, hemorrhage, inflammatory arthropathy, sarcoidosis
    - Castleman disease: Giant lymph node hyperplasia; lymphoproliferative disorder
      - Localized or multicentric (may be HIV-related)
    - Kikuchi disease: Occurs in neck; histiocytic necrotizing lymphadenitis
    - Rosai-Dorfman disease: Typically occurs in neck; sinus histiocytosis
    - Kimura disease: Eosinophilic hyperplastic lymphogranuloma
  - Infection
    - Bacterial > viral > fungal or parasitic
      - *Mycobacterium avium intracellulare*, *Mycobacterium scrofulaceum*, *Mycobacterium bovis*, and *Mycobacterium kansasii*
      - Other causes of granulomatous nodal inflammation are brucellosis and sarcoidosis
    - Cat scratch disease: Regional adenopathy 7-14 days after cat scratch or bite; infection by *Bartonella henselae*
    - BCG adenitis: Exaggerated expected nodal response → regional lymphadenitis 2 weeks to 2 years after BCG vaccination
      - Most common complication of BCG vaccination
  - Metastases
  - Hematological
    - Lymphoma (non-Hodgkin > Hodgkin) > leukemia

CLINICAL ISSUES

Presentation

- Most common signs/symptoms
  - Local swelling, tenderness, ± pain
    - Lymphadenitis: Very tender
    - Reactive adenopathy: Mildly tender
    - Metastatic, lymphomatous, and tuberculous nodes: Nontender

Treatment

- Anti-inflammatory agents or antibiotics (including antituberculous therapy) dependent on etiology
- Lymphoma: Systemic chemotherapy
- Metastatic: Surgery ± chemotherapy or irradiation

DIAGNOSTIC CHECKLIST

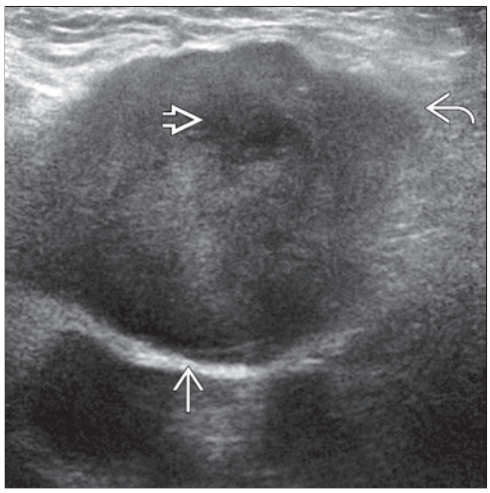
Consider

- Ultrasound diagnosis should be formulated on several recognized signs in conjunction with clinical presentation, rather than on just 1 or 2 signs
  - With this approach, ultrasound is overall accurate at determining presence and likely etiology of nodal pathology

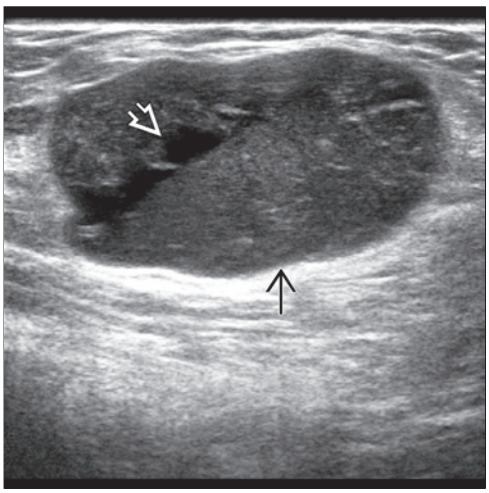
SELECTED REFERENCES

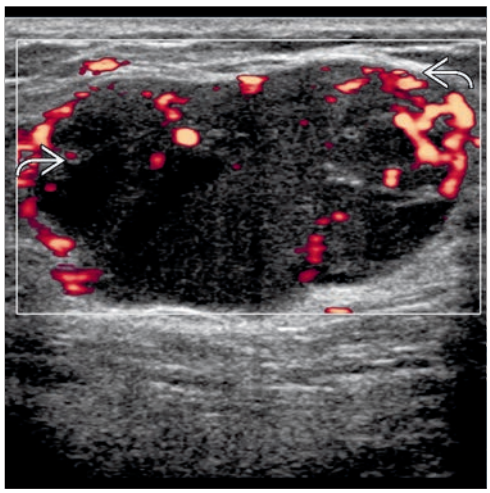
1. Dudea SM et al: Ultrasonography of superficial lymph nodes: benign vs. malignant. Med Ultrason. 14(4):294-306, 2012



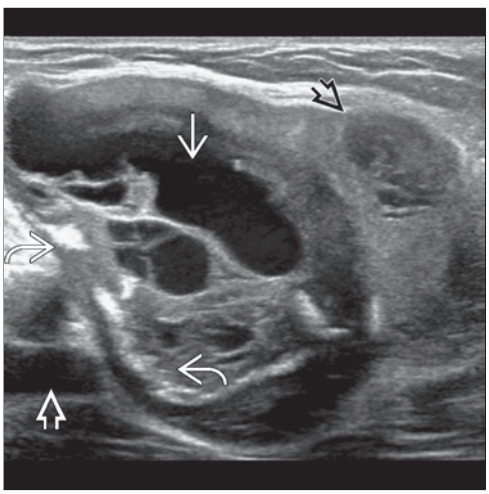


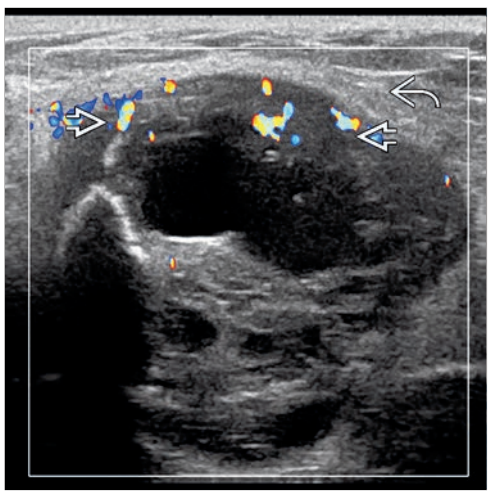
(Left) *Clinical photograph of the flank region shows a malignant-looking skin lesion in a patient with a chronic nonhealing skin ulcer. Histology revealed a high-grade adenocarcinoma with a focal of sweat gland with myoepithelial differentiation.* ***(Right)*** *Longitudinal ultrasound of the same patient shows an enlarged metastatic axillary node. The node is round with complete loss of the central fatty hilum. Note the mild intranodal necrosis and localized extracapsular spread.*





(Left) *Longitudinal ultrasound shows a metastatic groin lymph node in a patient with squamous cell carcinoma of the vulva. Moderate intranodal cystic component is present. Nodal cystic change is a common feature in squamous cell metastases.* ***(Right)*** *Longitudinal color Doppler ultrasound of the same lymph node shows the predominant peripheral hyperemia. The presence of peripheral hyperemia with no hilar vascularity is very suggestive of a metastatic node.*

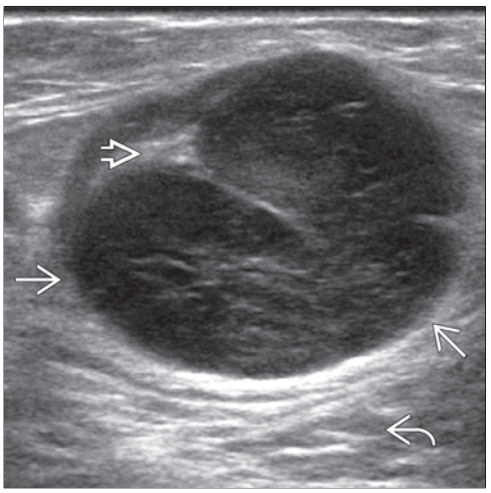


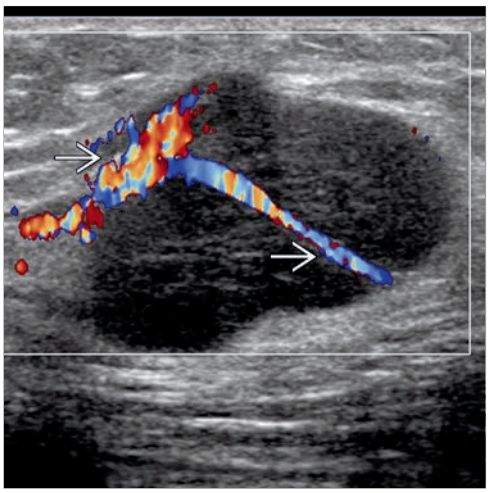


(Left) *Longitudinal ultrasound of a patient with telangiectatic-type osteosarcoma shows a metastatic groin node lying lateral to the femoral neurovascular bundle. There is a large cystic element with areas of mineralization and a 2nd discrete metastatic cortical focus.* ***(Right)*** *Transverse color Doppler ultrasound of the same metastatic node shows mild to moderate peripheral nodal vascularity. Mild perinodal soft tissue edema is present.*

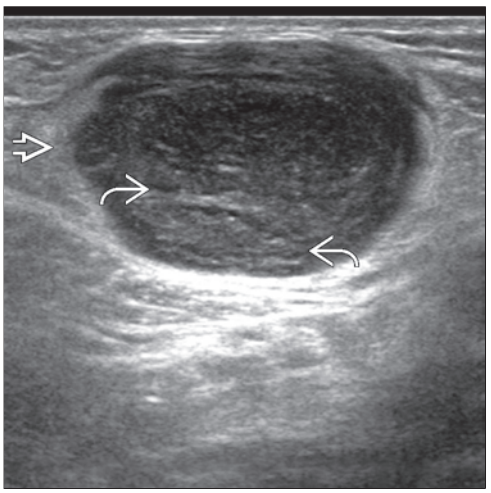
LYMPH NODE ABNORMALITY

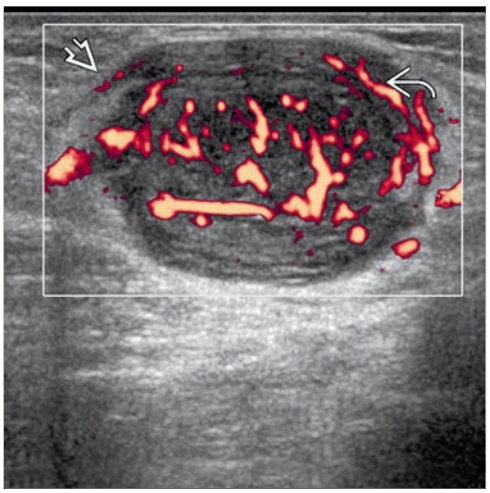
(Left) *Longitudinal ultrasound shows an enlarged, rounded epitrochlear lymph node in a patient with Hodgkin lymphoma. The node is markedly hypoechoic with moderate posterior acoustic enhancement due to uniform cellular infiltration producing few interfaces and facilitating beam transmission. Note the concentrically effaced fatty hilum.* ***(Right)*** *Transverse color Doppler ultrasound of the same lymph node shows marked cortical thickening and displaced central hilar vascularity.*



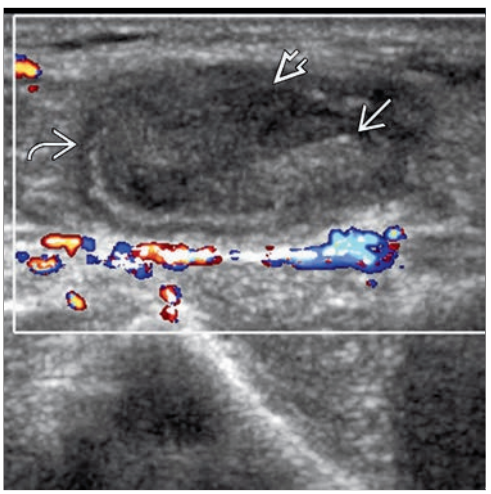


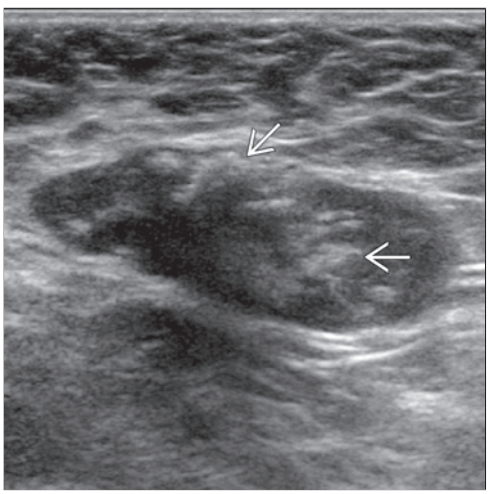
(Left) *Transverse ultrasound of a patient with lymphoma shows an ovoid hypoechoic groin lymph node. There is fine internal hyperechoic reticulation, which is a feature of lymphoma and malignancy. Mild perifocal edema and moderate posterior acoustic enhancement are present.* ***(Right)*** *Longitudinal power Doppler ultrasound of the same lymph node shows mixed central and peripheral vascularity. Note the absence of a central fatty hilum and mild extracapsular extension.*

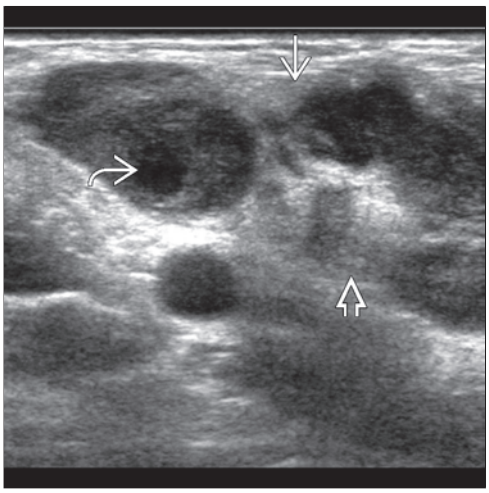


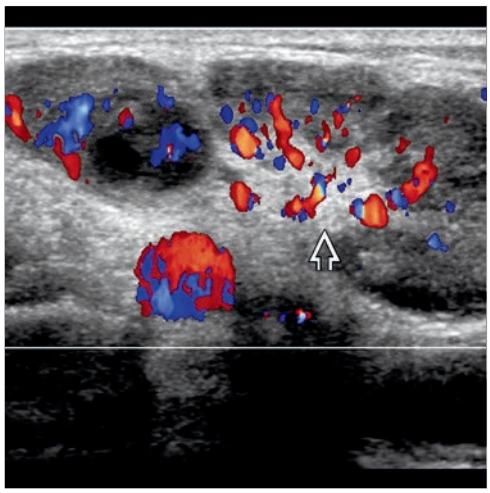


(Left) *Longitudinal color Doppler ultrasound shows an enlarged cystic axillary node due to BCG adenitis. There is a large area of intranodal liquefaction with relative hypoechogenicity and a fluid level due to necrotizing granulomatous inflammation. Note the posterior acoustic shadowing and mild degree of perinodal edema.* ***(Right)*** *Longitudinal ultrasound shows a healing tuberculous lymph node containing many small calcifications.*

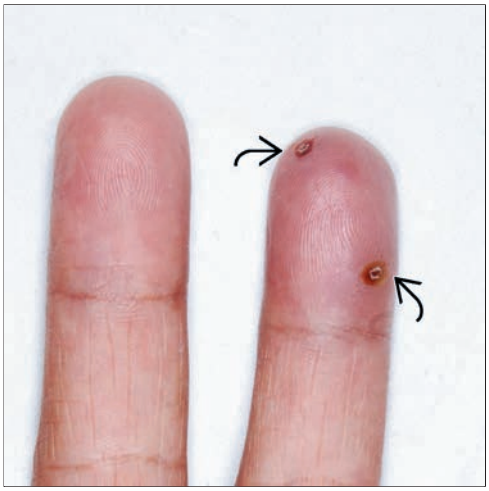


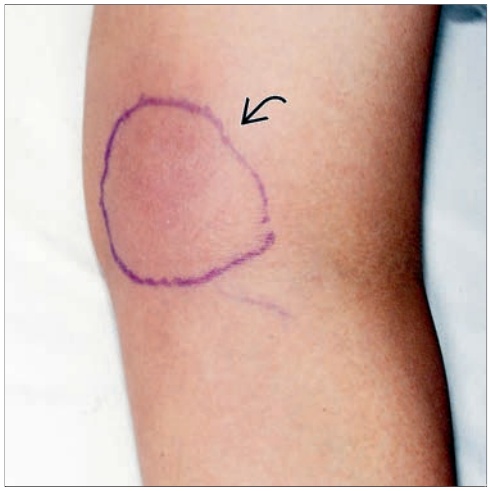




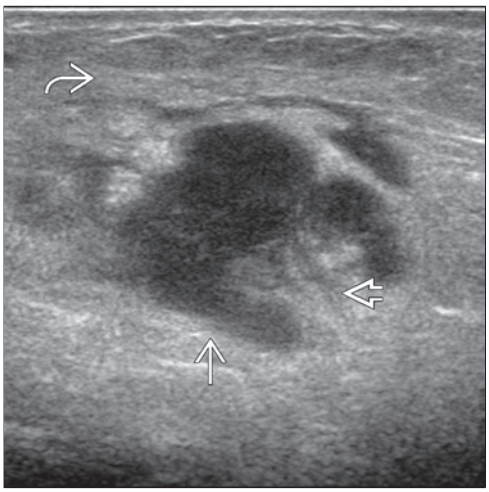


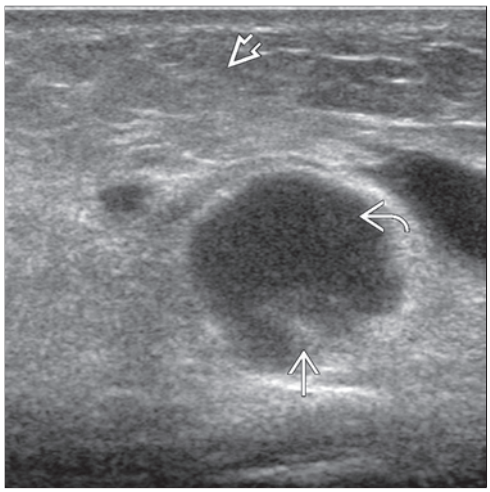
(Left) *Longitudinal ultrasound shows an enlarged groin lymph node with moderate cortical thickening and preservation of the echogenic hilum. There is a small cortical cystic component in keeping with suppurative lymphadenitis. Mild perinodal soft tissue edema is present.* ***(Right)*** *Longitudinal color Doppler ultrasound of the same node shows increased hilar vascularity. This suppurative lymphadenitis is due to enterococci infection.*





(Left) *Clinical photograph of the ring finger of a patient with a recent cat bite injury shows 2 small wounds (resulting from the cat bite) and associated mild skin erythema.* ***(Right)*** *Clinical photograph of the elbow region in the same patient shows epitrochlear swelling and cellulitis as outlined by the skin marking. This pattern of disease with epitrochlear swelling 1-2 weeks after a cat scratch to the hand is consistent with cat scratch disease.*





(Left) *Longitudinal ultrasound of the elbow region in the same patient shows an enlarged, irregular, oval-shaped epitrochlear lymph node with irregular cortical hyperplasia. The central fatty hilum is still preserved. There is severe perinodal soft tissue edema.* ***(Right)*** *Transverse ultrasound of the same node shows marked cortical hyperplasia with displacement of the fatty hilum. Severe perinodal soft tissue edema is present.*

SOFT TISSUE SARCOMA

Key Facts

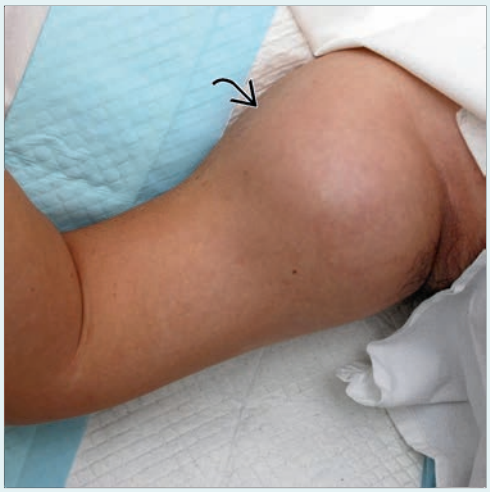
Terminology
- Malignant tumor arising from connective (mesenchymal) tissue other than bone

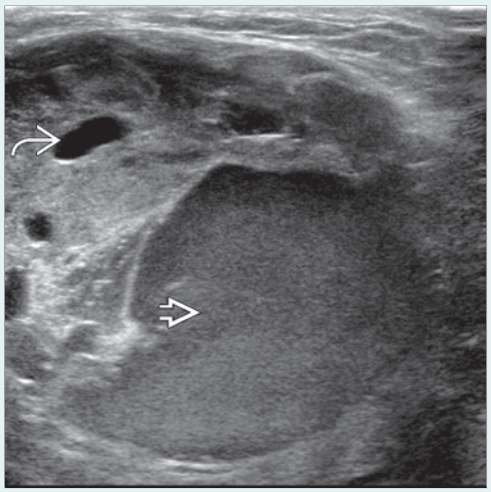
Imaging
- Large, heterogeneous, hypoechoic mass
  - Vast majority are located in deep (subfascial) tissues
- Most soft tissue sarcomas (STS) will have well-defined margin
  - As opposed to bone tumor, well-defined margin does not indicate benignity in soft tissue tumor
- ± myxoid tissue, necrosis, hemorrhage, or calcification
- Usually hypervascular with disorganized vascular pattern on color Doppler imaging
  - May be hypovascular or avascular
- Regional nodal metastases (uncommon)
- Neurovascular encasement
- Bone erosion or periosteal reaction (uncommon)
- Determine presence of tumor, ultrasound characteristics, and extent
- Identify which compartment is involved
- Evaluate regional nodes
  - Undertake fine-needle aspiration cytology if suspicious features
- MR is better than ultrasound at defining extent of large, deep tumors

Top Differential Diagnoses
- Benign soft tissue tumor
- Muscle metastasis
- Muscle hematoma

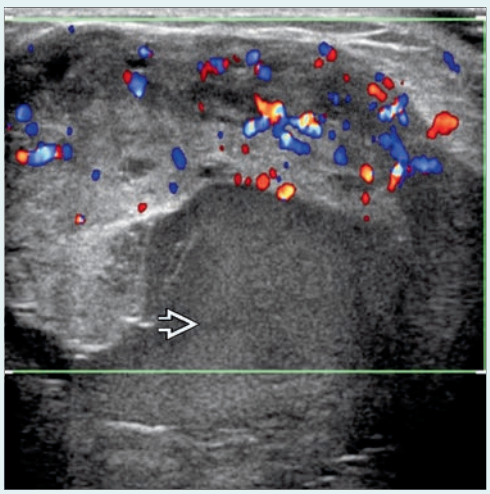
Diagnostic Checklist
- Consider STS in all growing, deep, soft tissue tumors that do not conform to known benign tumors
- Do not label any tumor as definitively benign unless firm diagnosis can be made based on appearances

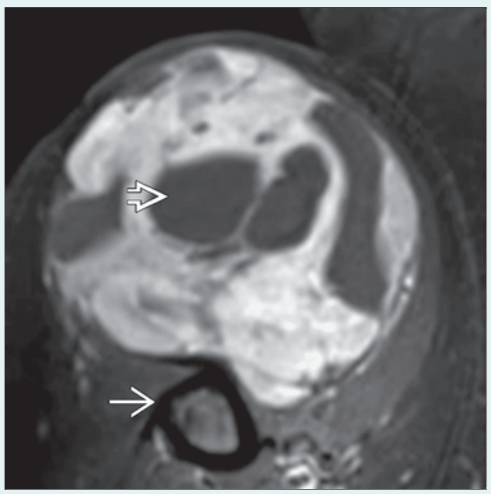
(Left) *Clinical photo shows an arm mass that had been slowly growing for 2 years in an adult patient.* ***(Right)*** *Transverse ultrasound of the same patient shows a large, well-defined, mixed cystic/solid tumor within the biceps brachii muscle. Low-level echoes consistent with hemorrhage are present within some cystic spaces. Some of these cystic spaces are clear. As opposed to a bone tumor, a well-defined border in a soft tissue tumor does not favor benignity.*





(Left) *Transverse color Doppler ultrasound of the same tumor shows moderate hypervascularity in the more solid component of the tumor. The cystic area is avascular. Ultrasound-guided biopsy was performed.* ***(Right)*** *Transverse T1WI C+ FS MR image of the same tumor shows avid tumoral enhancement with nonenhancing cystic areas. The tumor contacts the humerus. No cortical infiltration is evident. Histology revealed a synovial sarcoma.*





SOFT TISSUE SARCOMA

TERMINOLOGY

Abbreviations
- Soft tissue sarcoma (STS)

Synonyms
- Malignant soft tissue tumor

Definitions
- Malignant tumor arising from connective (mesenchymal) tissue other than bone

IMAGING

General Features
- Best diagnostic clue
  - Large, deep, soft tissue mass
- Location
  - Lower extremity (45%) > trunk (30%) > upper extremity (20%) > head & neck (5%)
    - Other than dermatofibrosarcoma protuberans, sarcoma arising within subcutaneous tissue is rare
      - Most malignant subcutaneous tumors are metastases or lymphoma
- Size
  - Variable
- Morphology
  - Heterogeneous, usually encapsulated mass

Ultrasonographic Findings
- Large, heterogeneous, hypoechoic mass
  - Usually located in deep (subfascial) tissues
  - Well encapsulated
  - Pseudocapsule is not usually seen as distinct structure
- Margin: Most STS will have a well-defined margin; irregular margins suggest aggressive fibromatosis, lymphoma, and inflammatory masses
- Myxoid tissue: Well-defined, intratumoral anechoic or hypoechoic areas
- Necrosis: Poorly defined, more centralized hypoechoic areas
- Calcification: Discrete, intratumoral, echogenic foci with acoustic shadowing
  - E.g., liposarcoma (5%), malignant fibrous histiocytoma (10%), synovial sarcoma (30%)
- Hemorrhage: Ill-defined, intratumoral, echogenic areas without acoustic shadowing; fluid levels
- Usually hypervascular with disorganized vascular pattern on color Doppler imaging
  - May be hypovascular or avascular
    - Large, deep-seated sarcomas often show minimal or no vascularity on color Doppler imaging
  - Vascular pattern may be orderly
  - Lymphoma very hypervascular
- Do not conform to recognized ultrasound appearances of other tumors, such as lipoma or nerve sheath tumor
  - Particularly true for superficial sarcomas as most superficial soft tissue tumors can be distinguished on basis of ultrasound characteristics
- Associated abnormality
  - Adjacent bone erosion or periosteal reaction/ scalloping (uncommon)
  - Regional nodal metastasis (not common)
    - Same ultrasound appearances as primary tumor
    - Enlarged, rounded node with loss of hilar echogenicity and peripheral/capsular rather than hilar vascularity
  - Neurovascular encasement

MR Findings
- Large, well-defined, soft tissue mass
- Heterogeneous pattern variably isointense on T1 and hyperintense on T2
- May have high T1 signal due to fat component in liposarcoma

Imaging Recommendations
- Best imaging tool
  - Ultrasound followed by MR
- Protocol advice
  - Determine presence of tumor, ultrasound characteristics, and extent
    - Identify which compartment is involved
      - If subfascial, identify which muscle compartment is involved
    - Confirm that tumor is well marginated
  - Determine relationship to neurovascular bundle and bone
    - Neurovascular bundle may be either separate from, in contact with, or encased (partial or complete) by tumor
  - Evaluate regional nodes
    - Undertake fine-needle aspiration cytology (FNAC) if suspicious
    - Remember proximal medial thigh node (of Cloquet) is normally large
  - MR is better than ultrasound at defining extent of large, deep tumors
  - Final diagnosis depends on histology of biopsy tissue
    - Perform ultrasound-guided biopsy of all suspected sarcoma except for well-differentiated liposarcomas
  - Ultrasound-guided biopsy for histology
    - Do not contaminate noninvolved compartment
    - Sample solid component under real-time scanning
      - Hyperemia on color Doppler imaging helps to identify areas of viable tumor
    - 16-gauge Tru-Cut core biopsy needle with 15-gauge coaxial system suitable for tissue typing and histological staging
      - Obtain at least 3 good cores from noncystic areas of tumor
      - Up to 20 biopsies may be necessary if tissue very friable
      - FNAC is not sufficient for initial diagnosis
      - FNAC is useful for detecting residual disease or recurrence

DIFFERENTIAL DIAGNOSIS

Benign Soft Tissue Tumor
- Characteristic ultrasound appearances to most common benign soft tissue tumors

Fibromatosis
- Soft tissue mass of variable echogenicity though usually hypoechoic with absent or mild vascularity on color Doppler imaging
- Irregular margins

SOFT TISSUE SARCOMA

Muscle Metastasis
- Smaller and less well defined than STS
- ± more peritumoral edema
- ± known primary tumor (majority) with disseminated disease

Muscle Hematoma
- Some tumors may bleed and present as muscle injury
  - Undertake further investigation (MR or PET imaging), follow-up or biopsy if suspicious

PATHOLOGY

General Features
- Etiology
  - Idiopathic
  - Radiation induced
- Classified according to tissue type rather than anatomical origin
  - For example; fibrosarcoma may not arise from fibrous tissue but histologically most resembles fibrous tissue
- Most STS are histologically high grade
- Grow centrifugally from single focus
  - Pseudocapsule formed by host reaction and compression of adjacent connective tissues
  - Reactive zone peripheral to pseudocapsule may contain tiny extensions (pseudopods) of tumor
    - May detach to give satellite nodules
- STS respects fascial and anatomical boundaries
  - Usually grow within compartment of origin
  - Involvement of > 1 compartment and bone/neurovascular bundle invasion are signs of aggressive tumor

Staging, Grading, & Classification
- Histological grading (as high, intermediate, or low grade) depends on
  - Degree of cellularity, cellular pleomorphism and level of dedifferentiation, mitotic activity, degree of necrosis, and infiltrative growth
- Surgical staging system
  - Stage I: Low grade
  - Stage 2: High grade
  - Stage 3: Metastasis
  - Stage A: Intracompartmental
  - Stage B: Extracompartmental

Gross Pathologic & Surgical Features
- Multilobulated mass ± attachment to adjacent structures
- Myxoid accumulation, hemorrhage, necrosis
- Pseudocapsule

Microscopic Features
- Liposarcoma
  - Well-differentiated variety: 40%
    - Mainly fat with pathognomic lipoblasts that confer malignancy
    - Thick (> 2 mm) septations
    - Nodular areas of nonlipomatous tissue
  - Myxoid variety (40%), round cell variety (10%), pleomorphic variety (5%), dedifferentiated variety (5%)
- Synovial sarcoma
  - Presence of keratin (epithelial marker) is diagnostic
    - Monophasic: 50-60%; mesenchymal spindle cell predominates
    - Biphasic: 20-30%; mesenchymal spindle cell and epithelial components
    - Poorly differentiated: 15-25%; high mitotic activity with necrosis

CLINICAL ISSUES

Presentation
- Most common signs/symptoms
  - Painless soft tissue mass enlarging over several months
- Clinical profile
  - Often indistinguishable from benign tumor

Demographics
- Age
  - 10-90 years; peak: 50 years
- Ethnicity
  - More common in whites
- Epidemiology
  - < 1% of adult cancer; 6% of childhood cancer
  - Malignant fibrous histiocytoma (25%), liposarcoma (15%), leiomyosarcoma (8%), malignant nerve sheath tumor (5%), dermatofibrosarcoma protuberans (5%), synovial sarcoma (5%), fibrosarcoma (5%), rhabdomyosarcoma (2%), epithelioid sarcoma, alveolar soft part sarcoma, extraskeletal Ewing tumor, lymphoma and others (15%), undifferentiated (15%)

Natural History & Prognosis
- Depends of histological grade and surgical resectability
  - 50% of high-grade tumors develop metastases despite adequate treatment
    - < 10% of those with metastases survive > 2 years

Treatment
- Most adult STS are chemoresistant (overall < 25% response rate)
- Surgical resection with wide margins
  - Resection margins should ↑ with high-grade tumor
- ± adjuvant radiotherapy to tumor bed
- Local recurrence rate ~ 10% for limb or limb-girdle STS
  - 80% of recurrences occur within 2 years of surgery

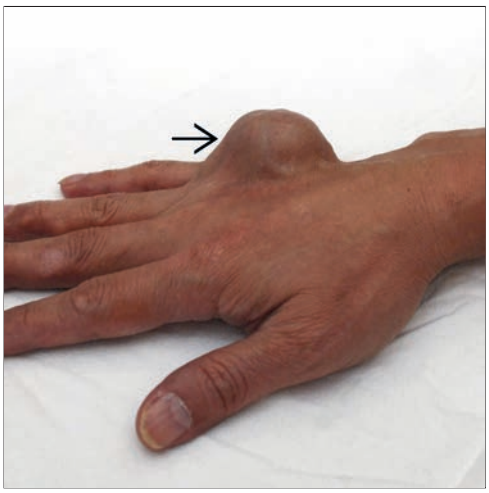
DIAGNOSTIC CHECKLIST

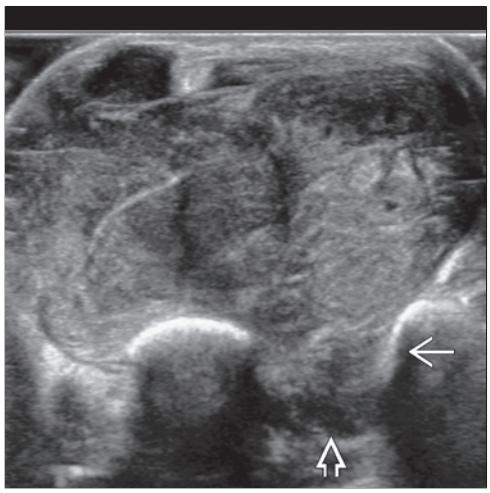
Consider
- STS in all rapidly growing soft tissue masses that do not conform to known benign characteristics

Image Interpretation Pearls
- Nearly all STS are well defined (i.e., sharp border does not equate to benign tumor)
- Do not label any tumor as benign based on ultrasound appearances unless sure about diagnosis

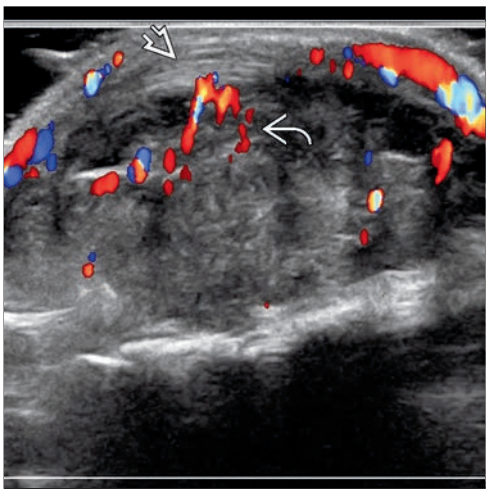
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1. Lakkaraju A et al: Ultrasound for initial evaluation and triage of clinically suspicious soft-tissue masses. Clin Radiol. 64(6):615-21, 2009



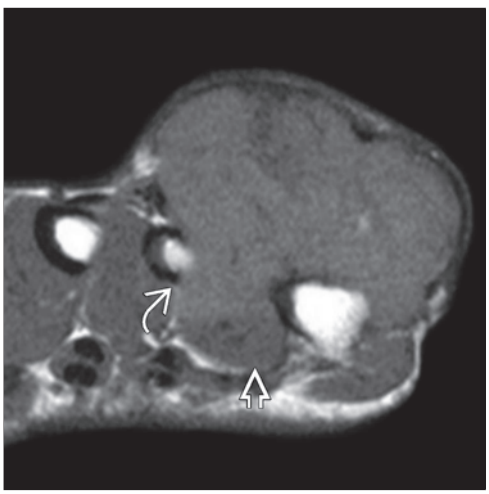


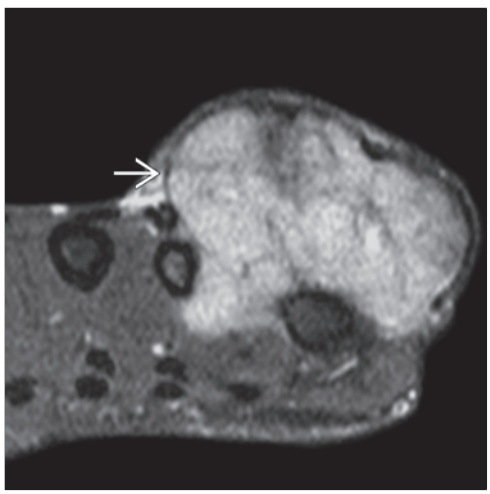
(Left) *Clinical photo shows a large mass on the dorsum of the hand. The mass had grown rapidly over the past year.* ***(Right)*** *Transverse ultrasound of the same swelling shows a large soft tissue mass on the dorsum of the hand extending deeply between the 4th and 5th metacarpal bones. Smooth bony scalloping is present on the ulnar side of the 4th metacarpal shaft. This scalloping may be due to pressure or bony resorption. It does not necessarily imply malignancy.*





(Left) *Longitudinal color Doppler ultrasound of the same tumor shows moderate tumor hyperemia. The mass has arisen deep to the extensor tendons, which are displaced superficially.* ***(Right)*** *Frontal radiograph of the hand in the same patient shows a long area of smooth, bony scalloping with cortical thinning of the 4th metacarpal bone deep to the large soft tissue mass. Radiographs show the degree and type of bony erosion better than ultrasound.*

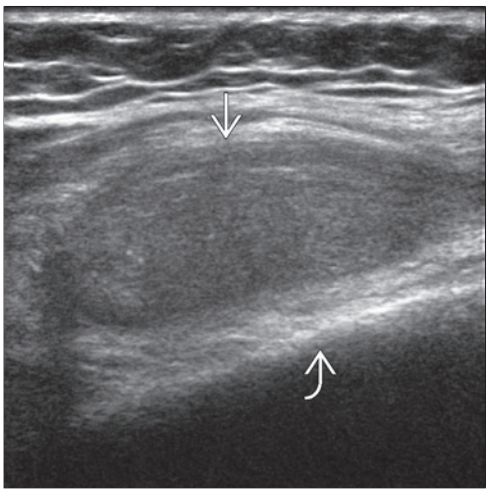


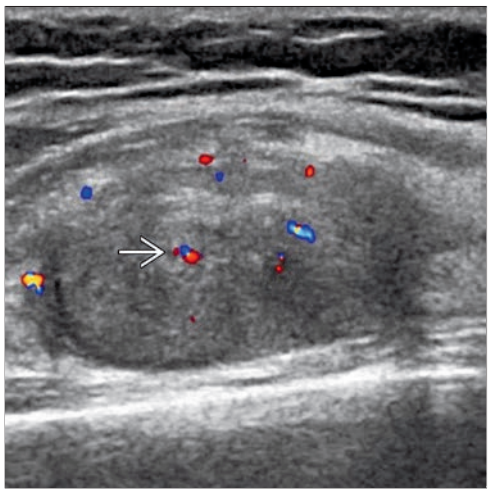


(Left) *Transverse T1WI FSE MR of the same tumor shows the soft tissue mass extending deeply between the 4th and 5th metacarpal bones. Note how the bony scalloping or erosion of the 4th metacarpal bone is more apparent than on ultrasound.* ***(Right)*** *Transverse T1WI C+ FS MR of the same tumor shows significant enhancement of the tumor mass. Percutaneous biopsy for histology was performed and revealed a clear cell sarcoma.*

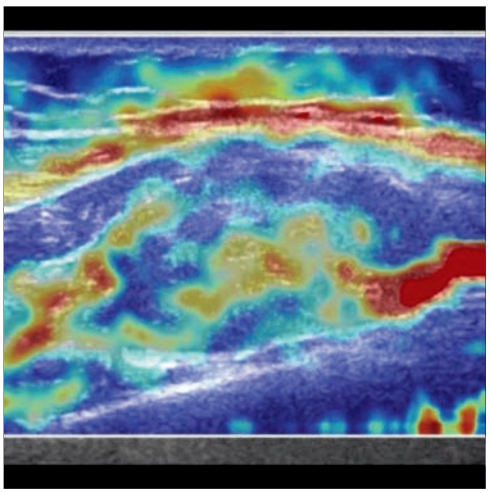
SOFT TISSUE SARCOMA

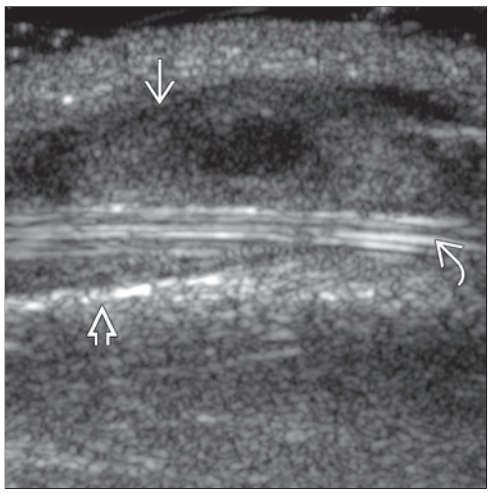
(Left) *Longitudinal ultrasound of a young adult patient with a painless thigh swelling for 1 month shows a well-defined, oval-shaped, homogeneous, hypoechoic soft tissue mass within the vastus intermedius muscle. No calcification or cystic change is present. The underlying femoral shaft is normal.* ***(Right)*** *Longitudinal color Doppler ultrasound of the same tumor shows mild, intratumoral hyperemia.*



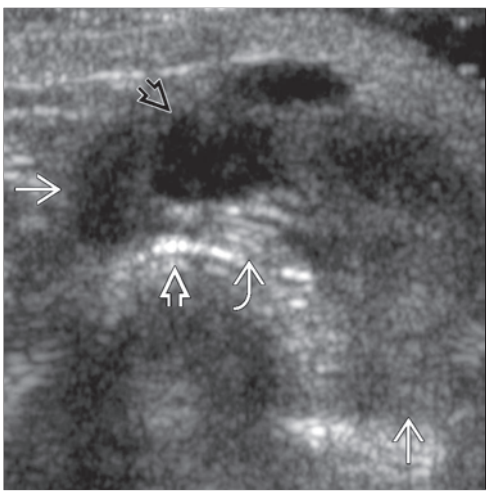


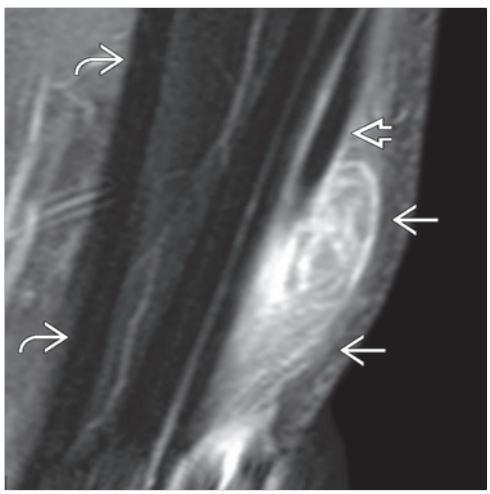
(Left) *Longitudinal ultrasound elastography of the same tumor shows variable tumoral elasticity. Red color represents stiff tissue while blue color represents normal soft tissue. Elastography in assessing soft tissue tumors is currently under investinvestigation. Histology revealed a fibromyxoid tumor of intermediate malignancy.* ***(Right)*** *Longitudinal ultrasound of the distal forearm shows a soft tissue mass encasing the flexor carpi ulnaris tendon and abutting the distal ulna.*



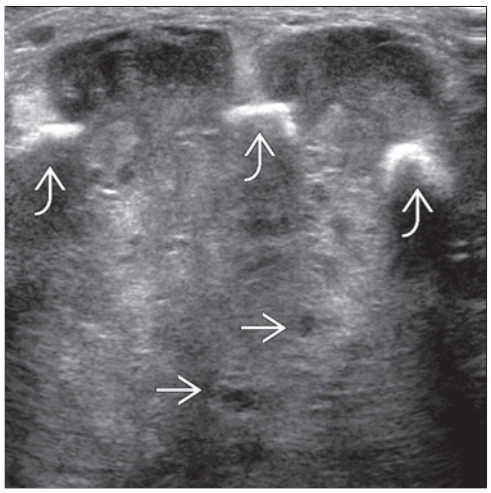


(Left) *Transverse ultrasound of the same tumor shows the soft tissue mass with small, cystic areas encasing the flexor carpi ulnaris tendon and partially encasing the distal ulna.* ***(Right)*** *Coronal T1WI C+ FS MR of the same tumor shows that the tumor is hypervascular and encases the flexor carpi ulnaris tendon abutting the ulna, but with no intramedullary extension. Percutaneous histology revealed a synovial sarcoma.*

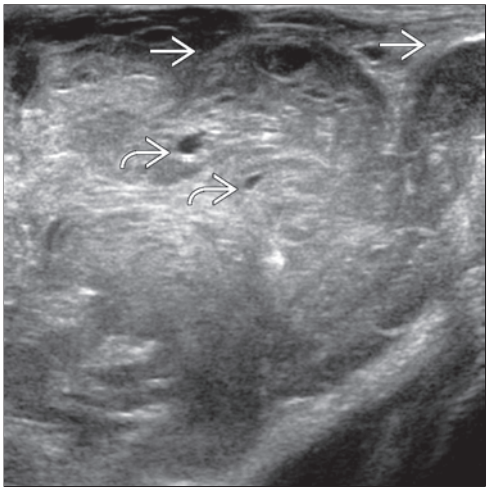


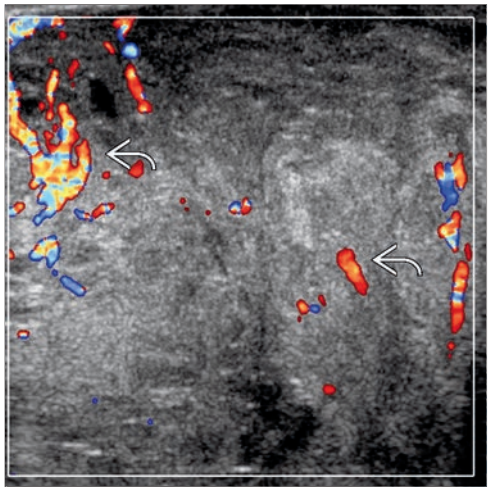






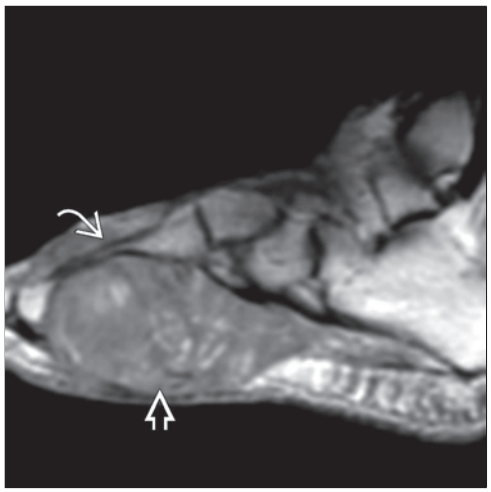
(Left) *Clinical photo of patient with known neurofibromatosis shows several small cutaneous neurofibromas. There is a large plantar swelling that had been increasing in size for 6 months.* ***(Right)*** *Transverse ultrasound of the same swelling shows a large, heterogeneous soft tissue tumor mass on the plantar aspect of the foot extending dorsally between the metatarsal bones. Small, intratumoral, cystic spaces are present.*





(Left) *Longitudinal ultrasound of the same tumor as previous image shows the lobulated tumor margin with small, intratumoral, cystic areas.* ***(Right)*** *Transverse color Doppler ultrasound of the same tumor shows moderate hypervascularity throughout the mass. Percutaneous biopsy for histology revealed a malignant peripheral nerve sheath tumor.*



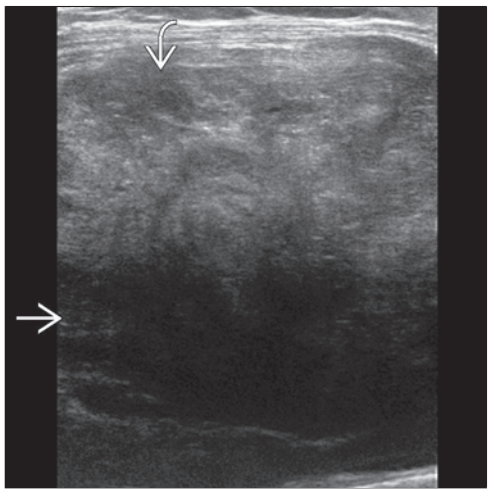


(Left) *Axial T2WI FS MR of the same tumor as previous image clearly shows the extent of this large tumor on the plantar aspect of the forefoot and midfoot.* ***(Right)*** *Sagittal T1W image of the same tumor shows a large plantar mass indenting the 4th metatarsal bone. MR is better than ultrasound at showing the extent of large tumors particularly in complex anatomical areas such as the foot.*

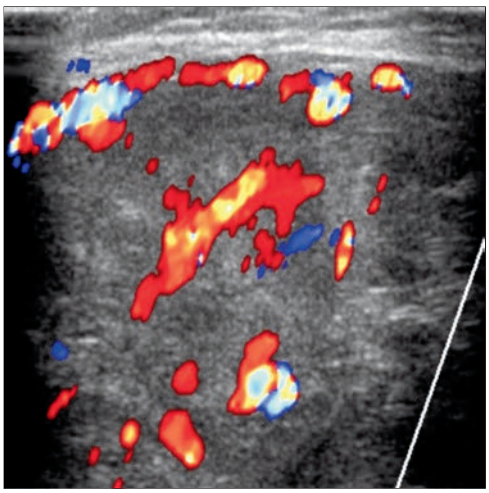
SOFT TISSUE SARCOMA

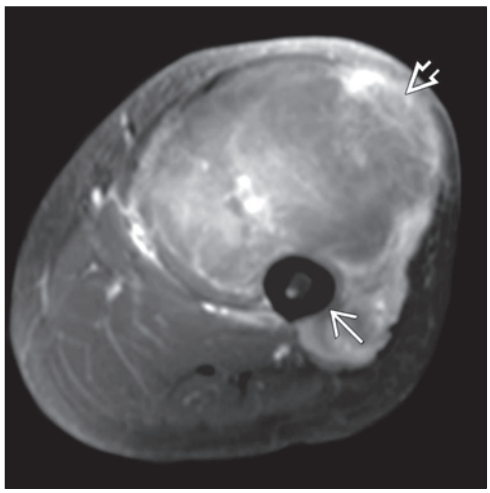
(Left) *Clinical photo shows a mass on the anteromedial aspect of the thigh that had been growing slowly for 10 months. Clinically, the mass was attached to the quadriceps tendon.* ***(Right)*** *Longitudinal ultrasound of the same swelling shows a large soft tissue mass with prominent acoustic attenuation leading to poor visibility of the deep aspects of the tumor. This finding is suspicious of a dense, fibrous-type tumor.*



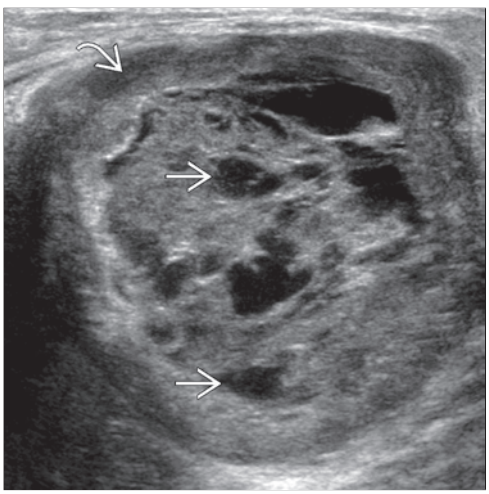


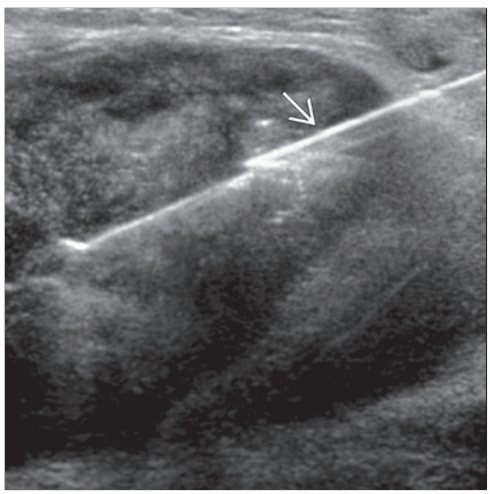
(Left) *Longitudinal color Doppler ultrasound of the same tumor as previous image shows moderate tumoral hypervascularity.* ***(Right)*** *Transverse T1 C+ FS MR of the same tumor shows how the moderately enhancing tumor mass is nearly completely encasing the femoral shaft without visible cortical erosion. MR is complimentary to ultrasound in this respect. There is an enhancing vessel within the femoral medullary canal. Histology revealed malignant fibrous histiocytoma.*

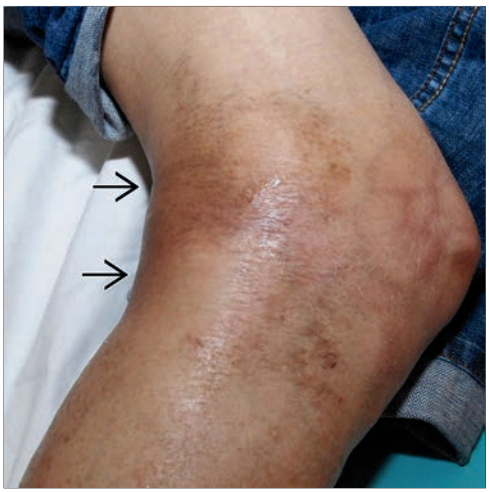


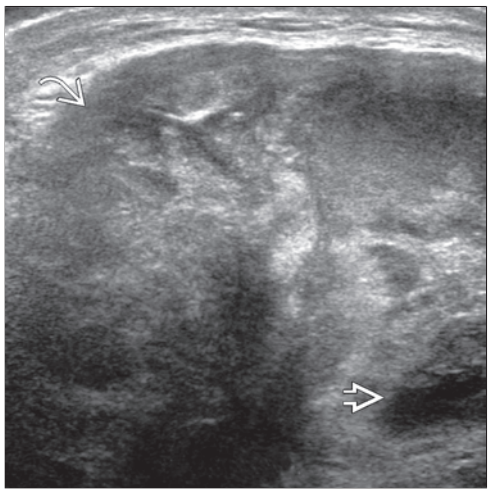


(Left) *Transverse ultrasound of a patient with a popliteal mass rapidly increasing in size over a 2-month period shows a heterogeneous, well-defined mass with solid and cystic components.* ***(Right)*** *Longitudinal ultrasound-guided biopsy of the same tumor using a coaxial 15-gauge needle and a 16-gauge Tru-Cut biopsy needle. Histology revealed monophasic synovial sarcoma. Percutaneous biopsy is an efficient and safe method for obtaining tissue for definitive diagnosis.*



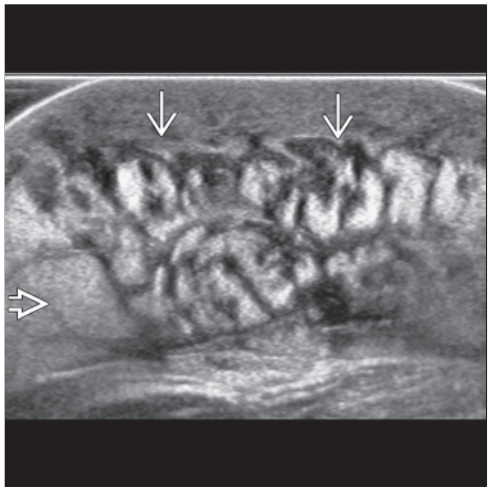




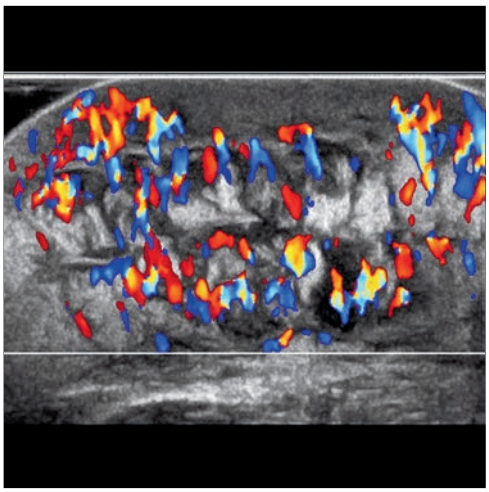


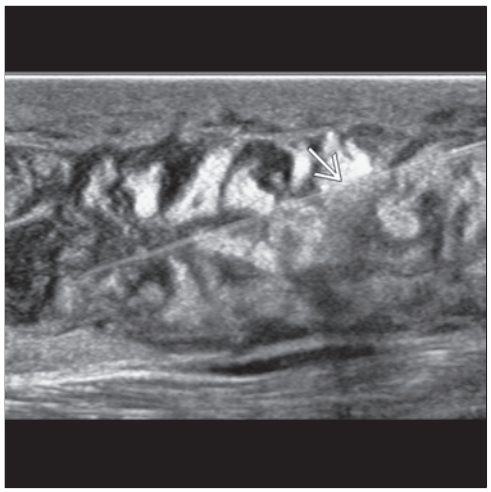
(Left) *Clinical picture shows a patient with popliteal fossa swelling that had been increasing in size for several months.* ***(Right)*** *Transverse ultrasound of the same swelling shows a large, heterogeneous tumor mass partially encasing the popliteal artery. The popliteal vein overlying the artery is compressed by the tumor and is not seen. Ultrasound-guided biopsy for histology revealed a leiomyosarcoma.*





(Left) *Clinical photo shows a patient with calf swelling, redness, and tenderness that had begun 1 month prior. Infection was suspected clinically.* ***(Right)*** *Transverse ultrasound of the same swelling shows a poorly defined area of quite intense subcutaneous edema and swelling. No fluid collection is present and there is no extension deep to the investing fascia. Moderate perilesional subcutaneous edema was present. The ultrasound diagnosis was atypical subcutaneous infection.*





(Left) *Transverse color Doppler ultrasound of the same tumor as previous image shows intense tumoral vascularity.* ***(Right)*** *Longitudinal ultrasound-guided needle biopsy was performed in view of atypical findings. Histology revealed an intense, polymorphous, abnormal lymphoid cell infiltrate with increased mitotic activity. Further staining confirmed a peripheral T-cell malignant lymphoma. Although not classified under soft tissue sarcoma, this is another malignant tumor of soft tissue.*

BONE TUMOR

Key Facts

Terminology
- Bone tumor: Neoplastic growth of tissue in bone
- Benign tumor: Tumor that does not metastasize
- Malignant tumor: Tumor that does metastasize
- Primary bone tumor: Tumor arising de novo in bone
- Secondary tumor: Tumor spreading to bone from malignant primary tumor located elsewhere

Imaging
- Ultrasound is not routinely used in standard work-up of bone tumors
  - Helpful as problem solver in particular instances
  - Used to guide biopsy of accessible bone tumors
- Ultrasound can assess
  - Tumor arising from bone cortex or intramedullary component once cortex is breached
  - Tumor matrix (if cortex is breached)
  - Flow dynamics of feeding arteries
  - Lymph node metastases (rare)
  - Bone tumor recurrence
- Radiography is most useful investigation
  - Radiographic abnormality is present in nearly all symptomatic bone tumors
  - Used to characterize tumor type and broadly grade aggressiveness of bone tumors
- MR used for
  - Local staging of bone sarcoma &/or assessing chemotherapy response
  - Characterizing and further evaluating benign bone tumors

Top Differential Diagnoses
- Osteomyelitis

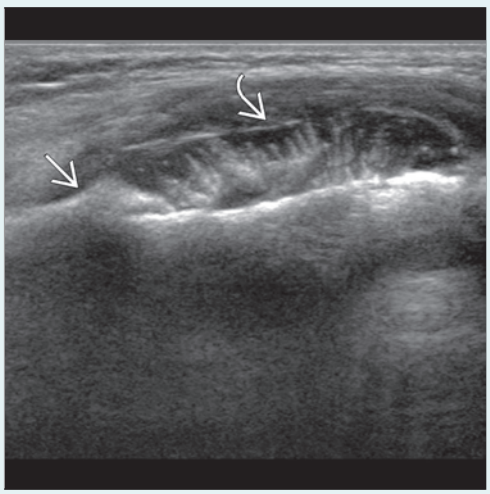
Diagnostic Checklist
- Consider tumor arising from bone in any deep-seated soft tissue mass

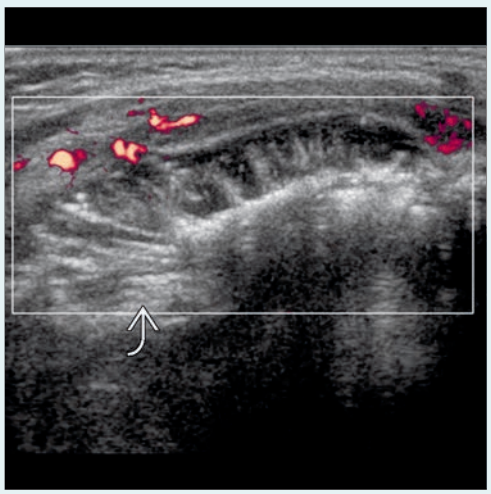
(Left) *Frontal radiograph of a skeletally immature child with a 4-week history of wrist pain and swelling shows a permeative osteolytic pattern of the distal radial metaphysis indicative of an aggressive bone lesion. There is a faint periosteal reaction. **(Right)** Sagittal T2* GRE MR obtained in the same patient the following day shows an aggressive bone tumor of the distal radial metaphysis with a surprisingly large extraosseous component. The tumor clearly extends beyond the physis.*





(Left) *Longitudinal ultrasound of the same lesion shows hypoechoic tumor matrix with radiating spicules of new bone suggestive of an osteogenic tumor. There is an ultrasonic Codman triangle at the proximal end of the tumor. **(Right)** Longitudinal color Doppler ultrasound shows mild marginal hyperemia. Note the radiating spicules of bone. This finding is seen in various bone tumors and is not unique for osteosarcoma, though ultrasound-guided biopsy did reveal osteosarcoma in this case.*





BONE TUMOR

TERMINOLOGY

Definitions

- Bone tumor: Neoplastic growth of tissue in bone
  - Benign tumor: Tumor that does not metastasize
  - Malignant tumor: Tumor that does metastasize
  - Primary bone tumor: Tumor arising de novo in bone
  - Secondary tumor: Tumor spreading to bone from malignant primary tumor located elsewhere

IMAGING

General Features

- Best diagnostic clue
  - Irregular bony destruction with soft tissue mass originating from bone
- Location
  - Any bone or bone area, though most commonly involves distal ends of long bones

Radiographic Findings

- Variable radiographic appearances
  - Centrally or eccentrically located within bone
  - Expansile or nonexpansile
  - Osteolytic, osteosclerotic, or mixed pattern
    - ± ground-glass opacification of matrix (fibrous tumor)
    - ± matrix mineralization
      - Chondroid-type mineralization (whorls, curves, popcorn-like)
      - Osteoid-type mineralization (hazy, cloud-like, solid)
  - Well-defined margin (narrow zone of transition)
    - Sclerotic or nonsclerotic rim
      - Well-defined margin favors nonaggressive tumor
  - Ill-defined margin (wide zone of transition)
    - Ill-defined margin favors aggressive tumor
  - ± cortical breach
  - ± extraosseous tumor expansion
  - ± periosteal ± tumoral new bone formation
    - Periosteal new bone formation: periosteum elevated or stimulated by tumor
    - Tumoral new bone formation: bone deposition by tumor matrix (osteogenic tumor)
  - Many types of periosteal or tumoral new bone formation
    - Lamellated: Single-layered or multilayered ("onion skin")
    - Spiculated, "sunburst," or "hair-on-end" patterns (represent tumoral rather than periosteal new bone)
    - Codman triangle (located at edge of extraosseous tumor extension)
    - Solid (mature)
  - Type of periosteal reaction is not a highly sensitive discriminator of tumor aggressiveness
    - Aggressive tumors may have no periosteal reaction or relatively benign type
    - However, spiculated, "sunburst," and "hair-on-end" patterns are quite specific for aggressive tumor

CT Findings

- Very specific for some tumors (e.g., intraosseous lipomas, osteoid osteomas)
- Used to guide biopsy for bone tumor with no extraosseous component

MR Findings

- Helps define local extent and often helps characterize both malignant and benign bone tumors
- For bone sarcoma, MR used to specifically define
  - Intramedullary tumor extent
  - Extramedullary tumor extent
  - Physeal involvement by tumor
  - Joint involvement by tumor
  - Neurovascular bundle involvement by tumor
  - Presence of skip metastases

Ultrasonographic Findings

- Ultrasound is not routinely used in standard work-up of bone tumors
  - Helpful as problem solver in particular instances
  - Increasingly used for guided biopsy of accessible bone tumors
- Bone tumor may be unexpected finding in patient undergoing ultrasound for nonspecific pain, discomfort, or mass
- Ultrasound can visualize component arising from bone cortex or intramedullary component once cortex is breached
- Osteochondroma
  - Pedunculated or sessile and metaphyseal in location
  - ± overlying hypoechoic cartilage cap
  - ± sequelae or complications of osteochondroma such as
    - Adjacent traumatic myositis or fat injury
    - Adjacent bursitis
    - Hemorrhage due to vascular injury
    - Pseudoaneurysm due to arterial injury
    - Nerve injury
    - Fracture of pedunculated osteochondroma
    - Malignant transformation
      - < 1% osteochondromas
      - Cartilage cap > 2 cm thick has high sensitivity and specificity for secondary chondrosarcoma
      - This diagnostic criterion is established on CT and MR but is not validated for ultrasound
- Tumor matrix
  - Ultrasound appearances generally mirror radiographic appearances
    - Usually hypoechoic matrix with irregular osteolysis
    - ± thin hyperechoic radiating intratumoral spiculated lines representing matrix ossification
      - These are indicative of aggressive bone tumor
    - ± cystic, hemorrhagic areas or fluid-fluid levels
    - ± irregular hyperechoic matrix mineralization
      - Retained osseous fragments can simulate matrix mineralization
    - ± pulsatile tumoral mass on real-time grayscale imaging
    - Variable hyperemia
    - ± Codman triangle and other types of periosteal reaction
  - Bone metastases are most common bone tumor encountered in routine clinical practice
    - Particularly in elderly patients
    - Have aggressive ultrasonic appearance that mimics bone sarcoma

- Primary tumors that commonly metastasize to bone are
  - Breast, lung, prostate, uterus, thyroid, bladder, kidney, pancreas, liver, and bowel
- Ultrasound is used to guide biopsy when extraosseous soft tissue mass is present or cortex is breached
  - Hyperemic areas on color Doppler imaging reflect areas of viable tumor
    - These areas should be targeted for biopsy
- Assessment of flow in large feeding artery (femoral, popliteal, subclavian, brachial) by spectral Doppler analysis
  - Can be done for all tumors irrespective of whether primary tumor is visible on ultrasound
  - Flow velocities can be calculated
  - Normal arterial flow is triphasic with reversal of flow in diastole
  - Metabolically active tumors may show substantial ↑ in antegrade diastolic flow
    - Generally accompanied by ↓ resistive indices
  - Change in flow dynamics can give indication of chemotherapy response
  - Assessment of intratumoral vessels by ultrasound is usually not that helpful
    - Too variable and even some deep-seated bone tumors may not have demonstrable vascularity on color Doppler imaging
- Ultrasound is very useful for assessing bone tumor recurrence
  - Recurrence of resected bone sarcomas usually occurs in juxtacortical soft tissue and not in bone
    - Recurrence usually seen as discrete mass in soft tissues close to resection site
  - Ultrasound is very useful when metallic prosthesis or fixation device in situ
    - Ultrasound assessment of juxtacortical tissues is not as affected by metal as CT or MR
- Ultrasound is used to assess lymph node metastases
  - Lymph node metastases are rare with primary bone tumor
  - More common with bone tumor recurrence
  - Can guide fine-needle aspiration for cytology (FNAC) of lymph node to confirm metastatic status

Imaging Recommendations

- Best imaging tool
  - Radiography
    - Radiographic abnormality is visible in nearly all symptomatic benign and malignant bone tumors
    - Radiographic abnormality may be absent in asymptomatic benign and malignant bone tumors
    - Radiography is used to characterize tumor type and grade tumor aggressiveness
  - MR imaging used for
    - Local staging of malignant primary bone tumors &/or assessing chemotherapy response
    - Characterizing and assessing extent and complications of benign bone lesions

DIFFERENTIAL DIAGNOSIS

Osteomyelitis

- Acute osteomyelitis and acute exacerbation of chronic osteomyelitis can simulate aggressive bone tumor on ultrasound
- Generally, acute osteomyelitis is associated with more pronounced inflammation than sarcoma
- Clinical and hematological parameters also help make distinction between infection and tumor
- Rapidly progressive symptoms, severe local tenderness, fever, other constitutional symptoms, and leucocytosis favor infection over tumor
- Biopsy may be necessary
- Quiescent chronic osteomyelitis may simulate nonaggressive bone tumor

PATHOLOGY

Staging, Grading, & Classification

- Grading according to degree of tumor spread and level of cellular differentiation

CLINICAL ISSUES

Presentation

- Most common signs/symptoms
  - Progressive increasing pain over weeks to months
- Other signs/symptoms
  - Enlarging palpable mass
  - Pain on weightbearing ± limp
  - Localized mild to moderate severity deep tenderness

Natural History & Prognosis

- Quite rapid, progressive deterioration if aggressive tumor
- Slow deterioration or quiescent symptoms if nonaggressive tumor

Treatment

- Nonaggressive: Treatment is largely related to symptoms and likelihood of sequelae
- Aggressive tumor: Resection ± limb-sparing reconstruction
  - ± Neoadjuvant and postoperative chemotherapy for sarcoma
  - ± reconstruction with metallic prosthesis or allograft

DIAGNOSTIC CHECKLIST

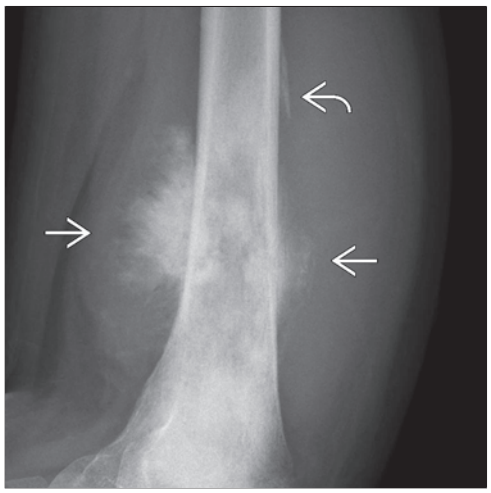
Consider

- Tumor arising from bone in any deep-seated soft tissue mass
  - Ensure that deep margin of any soft tissue tumor is seen
- Ultrasound has limited but occasionally very useful role in management of bone tumors

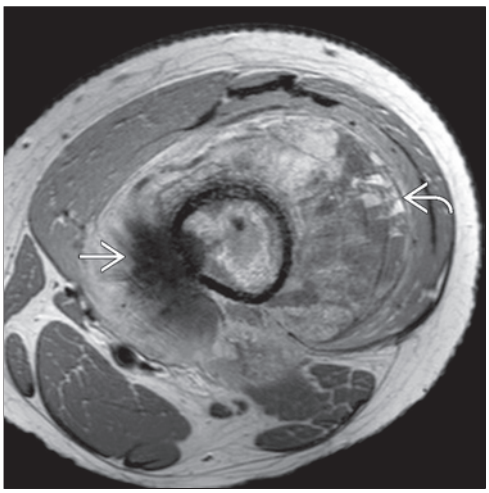
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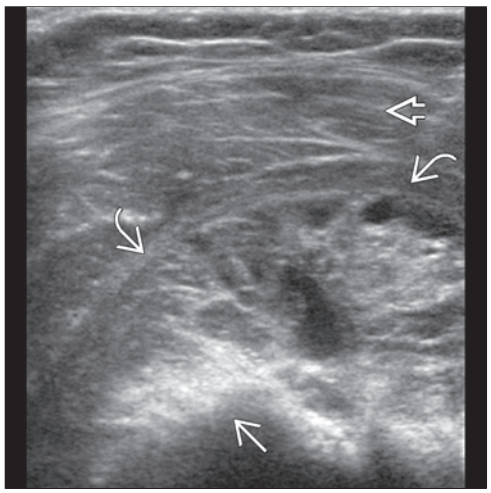
1. Saifuddin A et al: Pictorial review: ultrasonography of primary bone tumours. Clin Radiol. 53(4):239-46, 1998



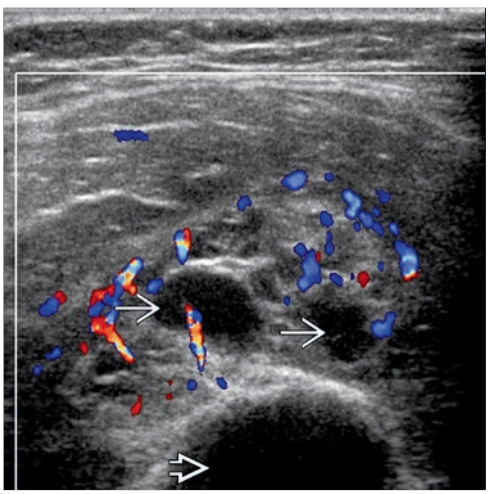


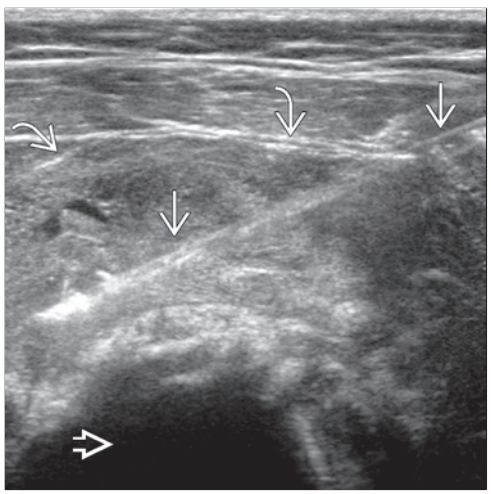
(Left) *Frontal radiograph of the distal femoral diaphysis shows altered bone texture associated with dense spiculated new bone formation medially with lamellar new bone formation laterally.* ***(Right)*** *Lateral radiograph of the same lesion shows dense spiculated new bone posteriorly and anteriorly with Codman triangle proximally. All of these appearances are consistent with osteosarcoma. Most bone tumors are diagnosed and characterized radiographically.*





(Left) *Axial PD FSE MR of the same lesion shows a large extraosseous soft tissue tumor with some fluid-fluid levels anteriorly and dense spiculated tumor new bone posteromedially.* ***(Right)*** *Transverse ultrasound of the anteromedial aspect of the same tumor shows dense spiculated tumoral new bone formation and a large extraosseous soft tissue component displacing the vastus medialis muscle anteriorly.*

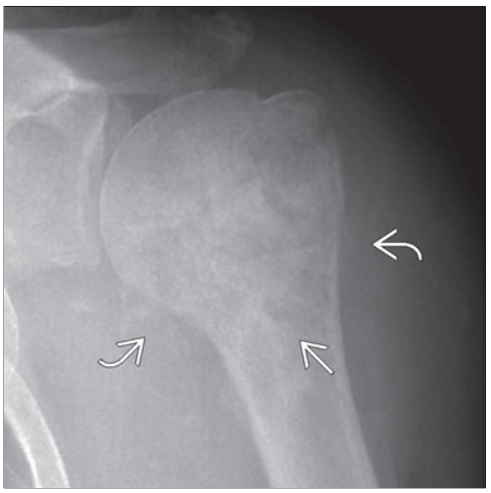


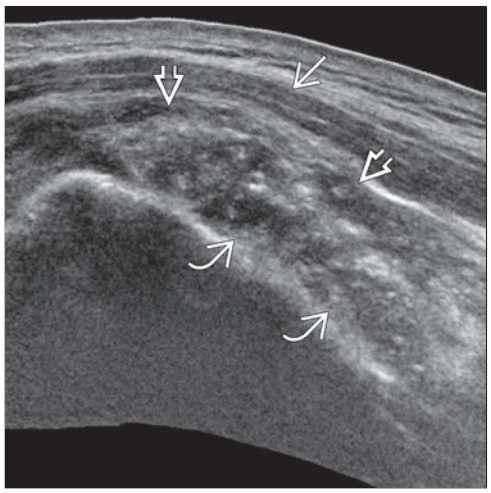


(Left) *Transverse color Doppler ultrasound shows moderate hyperemia of the extraosseous soft tissue component interspersed with some cystic areas. Hyperemia is a reliable sign of viable tumor, which will usually provide a good yield with biopsy. Note the femur.* ***(Right)*** *Transverse ultrasound of same lesion shows the biopsy needle located within the extraosseous tumor mass. Ultrasound is an efficient method of biopsying tumors with an accessible soft tissue component. Histology revealed osteosarcoma. Note the femur.*

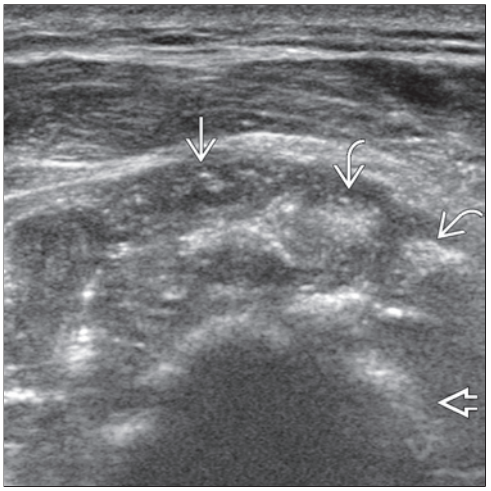
BONE TUMOR

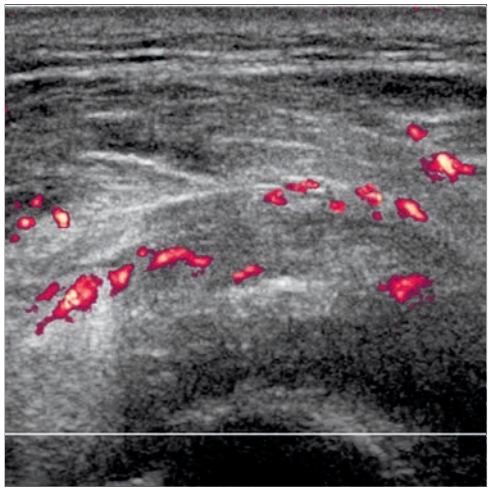
(Left) *Frontal radiograph in a 53-year-old man with shoulder pain shows patchy osteosclerosis of the proximal humeral metaphysis associated with faint spiculated extraosseous new bone formation. This is consistent with an aggressive bone lesion.* ***(Right)*** *Longitudinal extended field-of-view ultrasound shows spiculated new bone formation extending from the lateral humeral cortex with a moderate-sized extraosseous soft tissue component displacing the thin overlying deltoid muscle.*



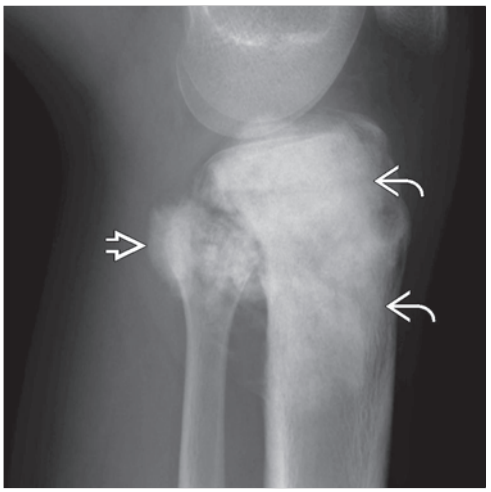


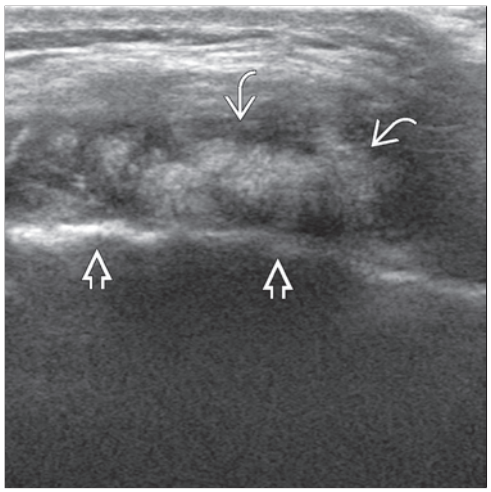
(Left) *Transverse ultrasound of the same lesion shows cloud-like echogenic areas within a hypoechoic extraosseous tumor matrix, which are suggestive of osteoid deposition together with many smaller echogenic speckles. Note the irregular blurred humeral cortical margin.* ***(Right)*** *Transverse power Doppler ultrasound of the same lesion shows mild hyperemia of the extraosseous component. Ultrasound-guided percutaneous biopsy (not shown) revealed osteosarcoma.*



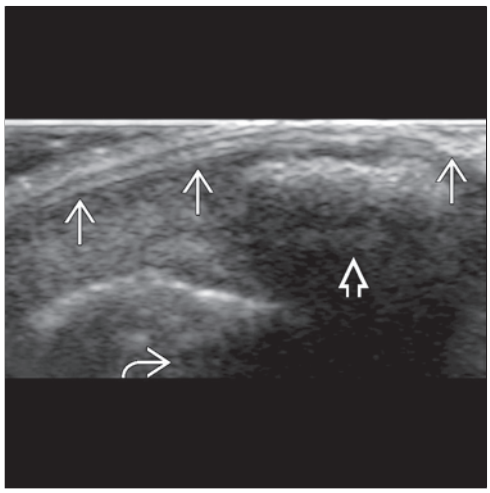


(Left) *Lateral radiograph of the proximal leg in a young patient shows a sclerotic tumor of the proximal tibia with a large, densely mineralized extraosseous component posteriorly.* ***(Right)*** *Longitudinal ultrasound of the same lesion shows quite densely echogenic extraosseous soft tissue component. This cloud-like echogenicity is suggestive of osteogenic tumor. Ultrasound-guided percutaneous biopsy (not shown) revealed osteosarcoma. Note the unsharp tibial cortex.*

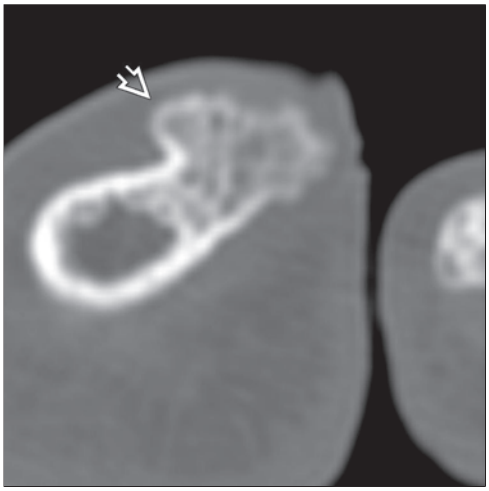






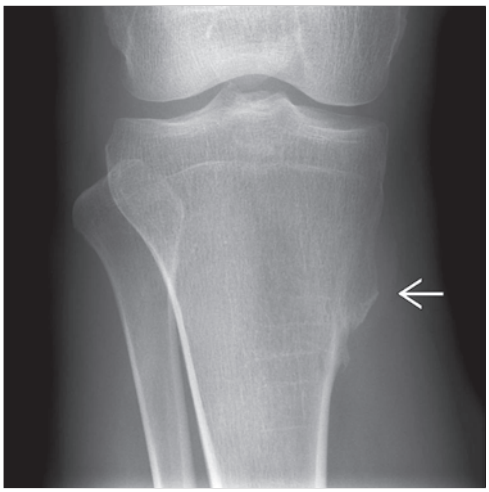


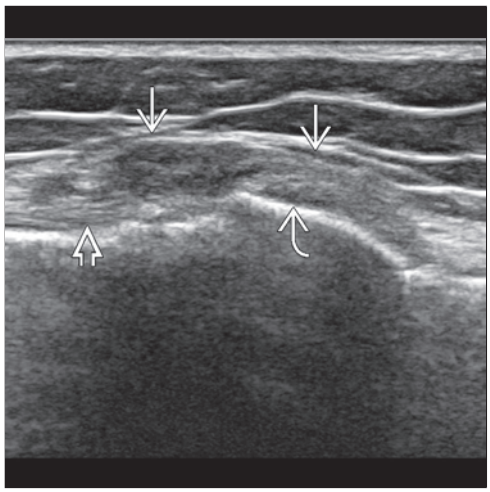
(Left) *Photograph of the medial forefoot shows a seemingly fleshy mass protruding from the undersurface of the big toe nail laterally. The lateral aspect of the nail is elevated as a result.* ***(Right)*** *Transverse ultrasound shows an echogenic protuberant subungual mass on the lateral side of the big toe. The mass is lifting the nail upwards. Continuity with the underlying distal phalanx cannot be fully assessed with ultrasound due to acoustic shadowing.*





(Left) *Coronal CT with bone window shows an exostosis arising from the medial aspect of the distal phalanx. Continuity with the medullary canal is not as distinct as that of nonsubungual osteochondromas. This is a feature of subungual exostoses, which are radiologically similar though pathologically distinct from other osteochondromas.* ***(Right)*** *3D CT reconstruction of the same lesion shows the subungual exostosis. These nearly always occur on the medial aspect of the big toe and may be induced by trauma.*

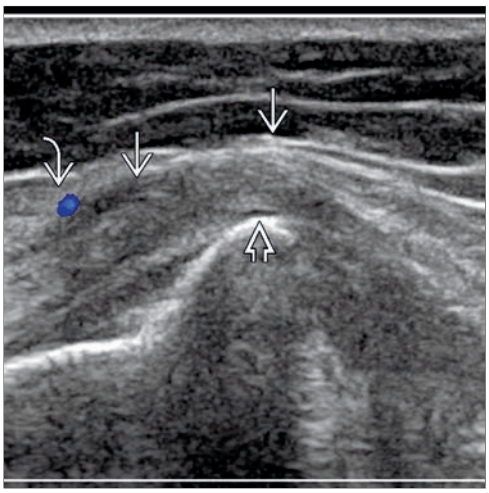


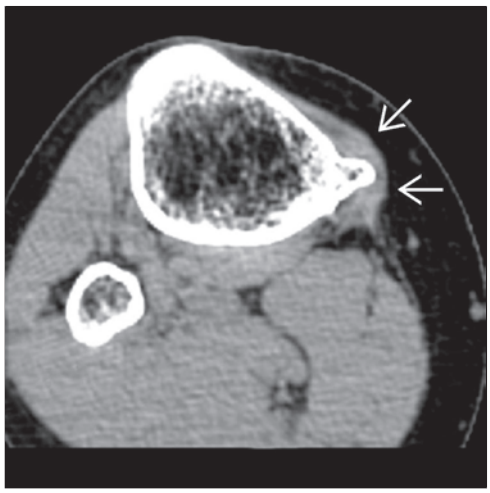


(Left) *Frontal radiograph shows a small sessile osteochondroma located on the medial aspect of the proximal tibial metaphysis.* ***(Right)*** *Longitudinal ultrasound of the same lesion shows a thick-walled chronic bursitis overlying this osteochondroma. The medial collateral ligament is seen just proximally. The very thin hypoechoic layer is a thin cartilage cap. Adventitious bursa develop in sites where friction occurs. They may become inflamed, infected, or hemorrhagic.*

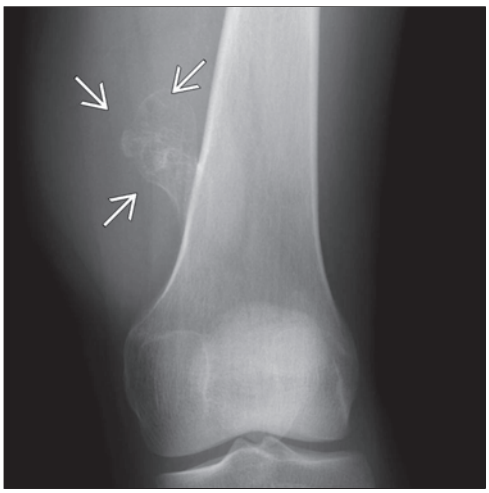
BONE TUMOR

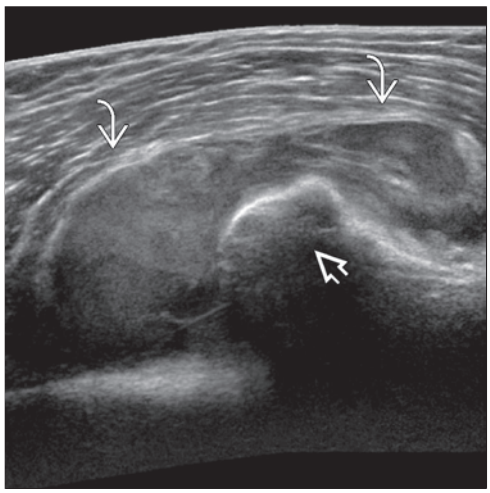
(Left) *Transverse color Doppler ultrasound of the same lesion shows only minimal hyperemia of the thickened soft tissues overlying the tibial osteochondroma. The very thin hypoechoic cartilage cap is visible. **(Right)** Transverse CT shows soft tissue thickening suggestive of chronic thick-walled bursitis overlying the osteochondroma on the medial aspect of the proximal tibia. Soft tissue thickening such as this overlying a osteochondroma is normally symptomatic.*



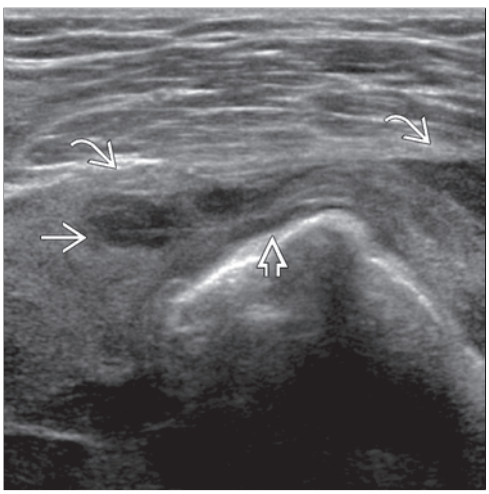


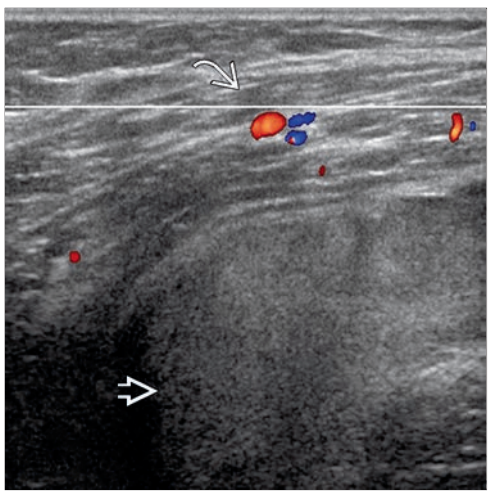
(Left) *Frontal radiograph shows a large pedunculated osteochondroma on the medial side of the distal femoral metaphysis. This lesion was symptomatic and referred for ultrasound examination. **(Right)** Longitudinal ultrasound with extended field-of-view of the same lesion shows a bursa distended with hemorrhage overlying the femoral osteochondroma. Both chronic bursitis and hemorrhagic bursitis are not uncommon causes of osteochondroma-related pain.*

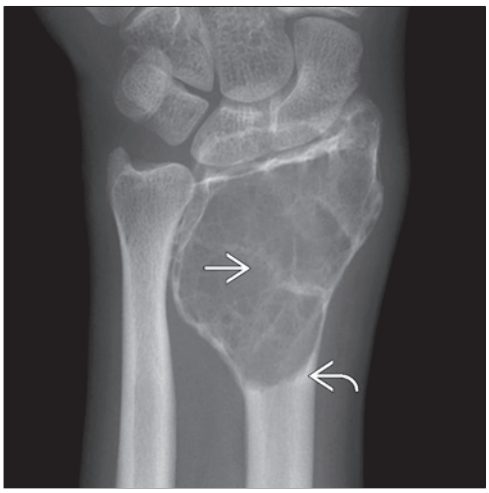




(Left) *More coned-down longitudinal ultrasound of the same lesion shows a thin hypoechoic cartilage cap overlying the osteochondroma. There is some gravity-aided sedimentation of hemorrhagic bursal content. The thin bursal wall is visible. No osteochondroma fracture was evident on ultrasound. **(Right)** Transverse color Doppler ultrasound shows mild hyperemia around the hemorrhagic bursitis. Color Doppler ultrasound also helps confirm the nonsolid nature of the bursal content.*

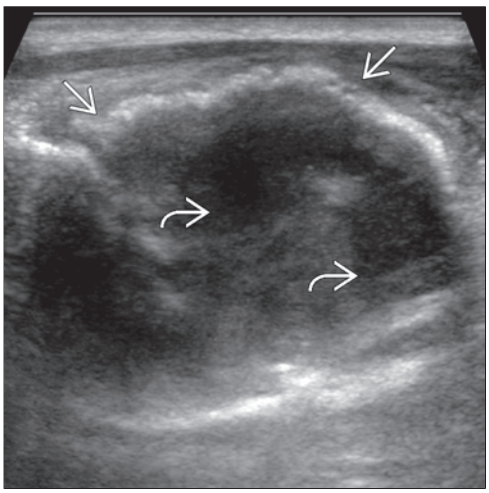


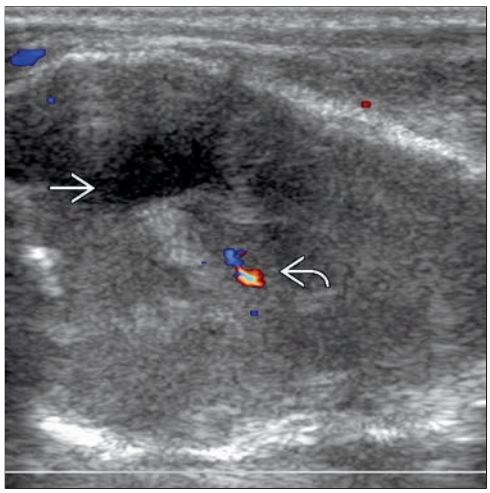




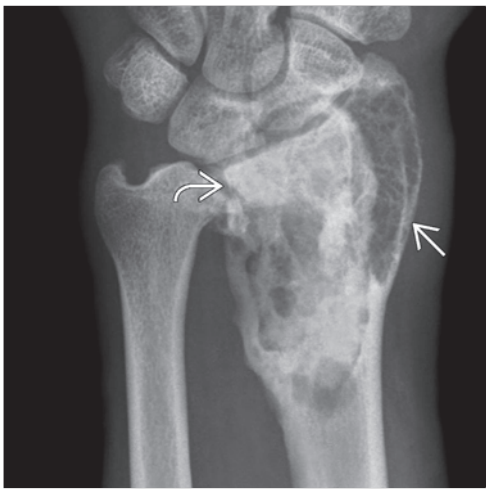


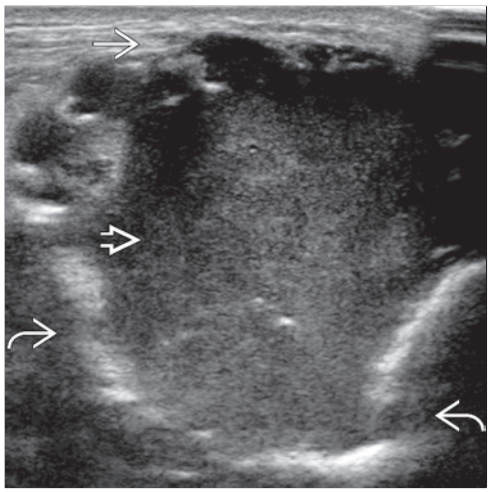
(Left) *Frontal radiograph in a young, skeletally mature patient shows a moderately expansile lytic subarticular tumor with a well-defined, nonsclerotic margin. The tumor has thinned cortices with traversing septa. These appearances are consistent with either a giant cell tumor, a giant cell tumor with secondary aneurysmal bone cyst (ABC) formation, or else a primary ABC.* ***(Right)*** *Lateral radiograph of the same lesion shows very similar appearances. The cortex is thinned but not breached.*





(Left) *Transverse ultrasound of the same lesion as previous radiographs shows an expansile distal radius. As the cortex is thinned, one can appreciate the partially cystic nature of the tumor with some fluid levels. No extraosseous tumoral component was present.* ***(Right)*** *Transverse color Doppler ultrasound demonstrates only mild hyperemia of the tumoral matrix. The partially fluid nature of the tumor can be appreciated even though the cortex was not breached, US-guided biopsy was undertaken, revealing giant cell tumor.*

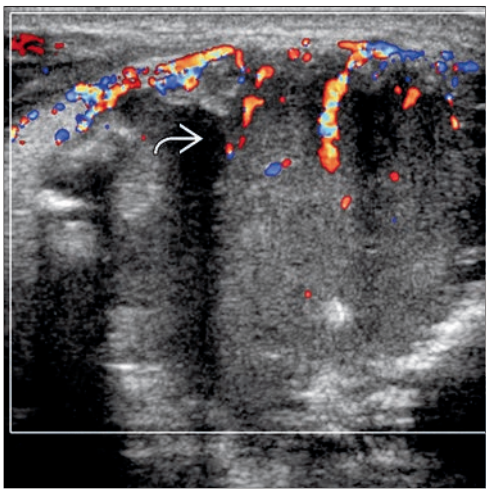


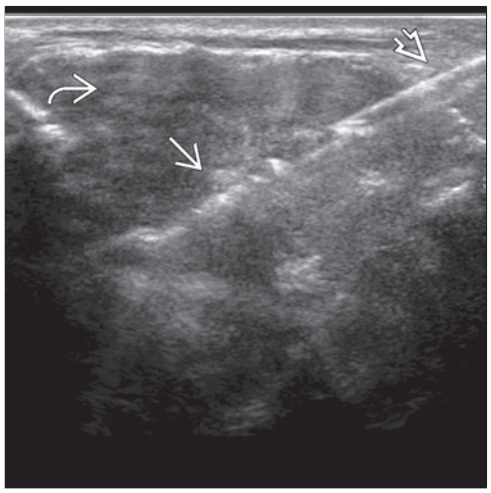


(Left) *Frontal radiograph shows a moderately expansile, partially sclerotic, partially osteolytic, subarticular tumor of the distal radius with a narrow zone of transition. Giant cell tumor was a consideration, but the appearances are atypical.* ***(Right)*** *Longitudinal ultrasound shows the breached dorsal cortex allowing appreciation of the homogeneous almost fluid-like content of the tumor matrix. Note the residual unsharp interrupted expanded cortex.*

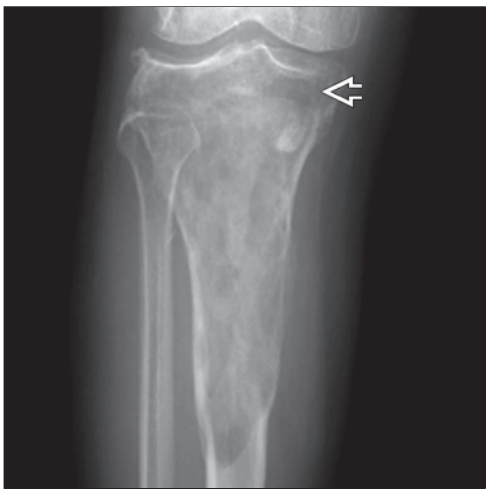
BONE TUMOR

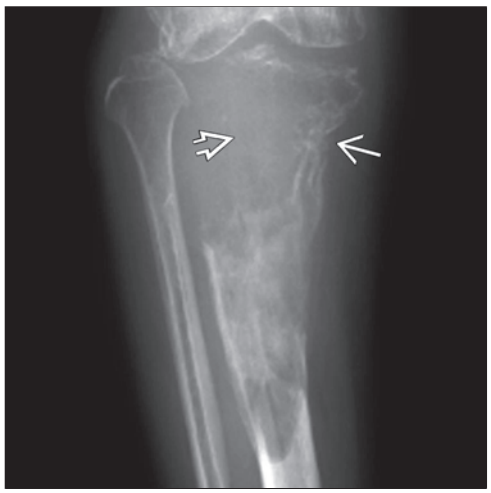
(Left) *Longitudinal color Doppler US shows moderate marginal hyperemia extending down into the tumor matrix. The presence of tumoral hyperemia is an excellent indicator of viable tumor tissue.* ***(Right)*** *Longitudinal US shows core biopsy of the bone tumor using a coaxial system with a 15-g coaxial needle transmitting a 16-g Tru-Cut biopsy needle. Multiple biopsies can be taken with minimal disruption of extratumoral tissue. Histology revealed giant cell tumor of bone.*



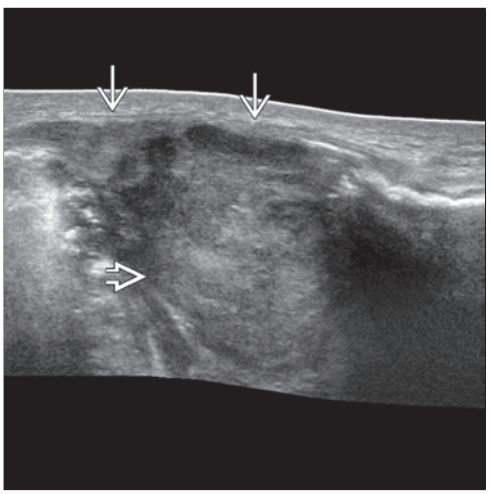


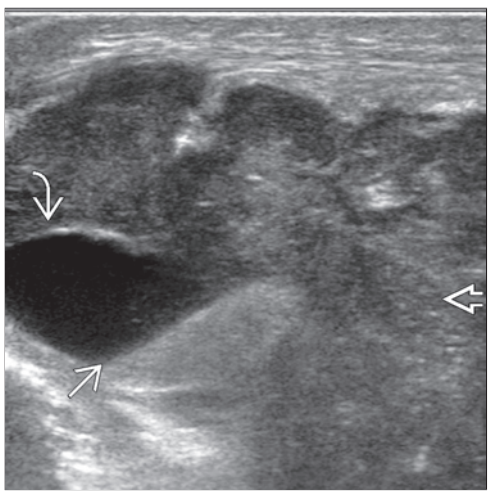
(Left) *Frontal radiograph in an 82-year-old woman shows a mildly expansile tumor of the proximal tibia consistent with fibrous dysplasia. Other than a lucent area in the medial tibial condyle, no particularly suspicious features are present.* ***(Right)*** *Frontal radiograph of the same lesion 12 months later shows a large osteolytic component with a moderate compression fracture of the proximal tibia. These appearances are compatible with malignant transformation of fibrous dysplasia.*

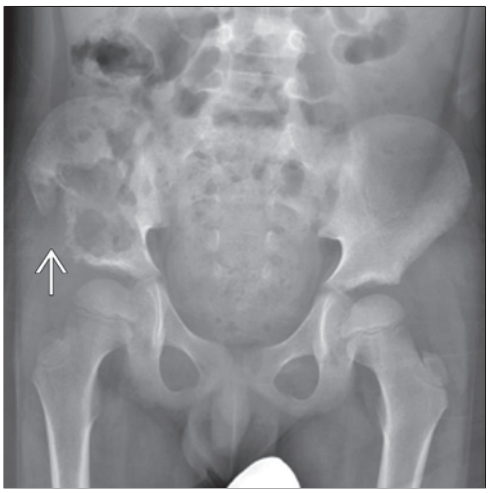


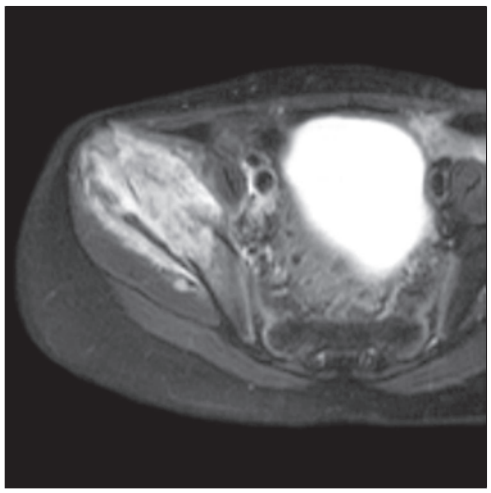


(Left) *Longitudinal ultrasound of the same tumor shows osteolysis of the proximal tibial cortex. This allows visibility of the large hypoechoic tumor filling the medullary canal.* ***(Right)*** *Longitudinal ultrasound shows a cystic area within the hypoechoic tumor matrix with a fluid-fluid level. The tumor matrix was moderately hypervascular on color Doppler imaging (not shown). Ultrasound-guided biopsy revealed high-grade osteosarcoma. An above-knee amputation was performed.*

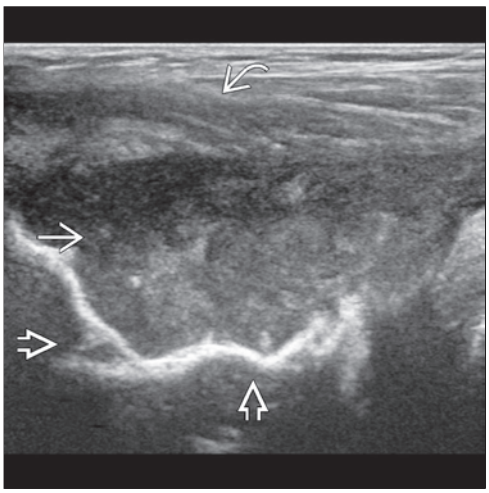


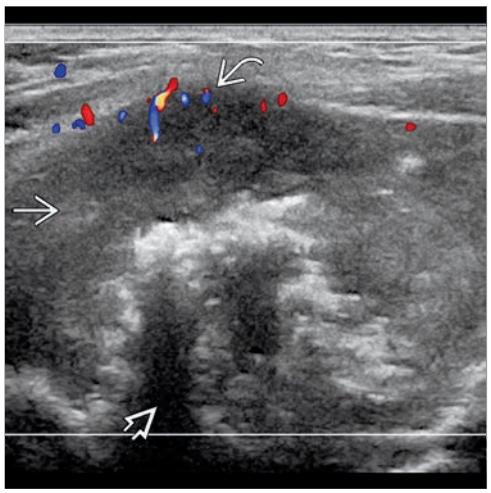




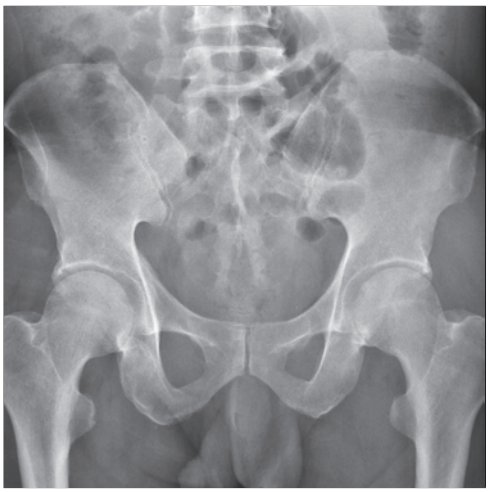


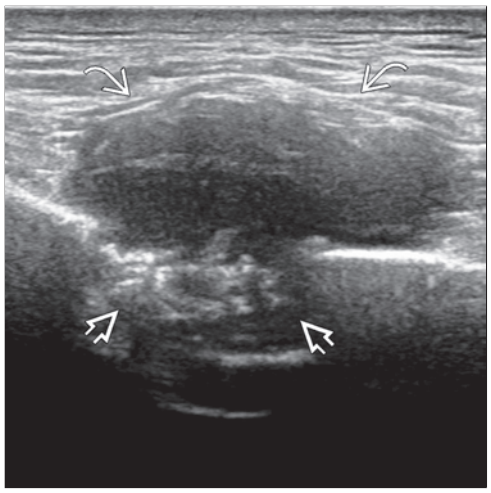
(Left) *Frontal radiograph of the pelvis in a child shows a large, irregular osteolytic area* ➔ *in the supraacetabular portion of the right hemipelvis, partially obscured by bowel gas.* ***(Right)*** *Axial T1WI C+ FS MR of the same area shows a large, irregular, mildly expansile mass in the right ilium extending into the iliacus and gluteal muscles. An additional smaller lesion was present in the posterior elements of L5 (not shown).*





(Left) *Transverse oblique ultrasound of the same patient shows irregular osteolysis* ➔ *of the iliac bone with a large hypoechoic tumor* ➔ *deep to the gluteal musculature* ➔. ***(Right)*** *Longitudinal oblique color Doppler ultrasound shows irregular iliac bone osteolysis* ➔ *surrounded by hypoechoic tumor matrix* ➔. *Mild tumor hyperemia* ➔ *was present on color Doppler imaging. Ultrasound-guided biopsy (not shown) revealed Langerhans cell histiocytosis (LCH) of bone.*

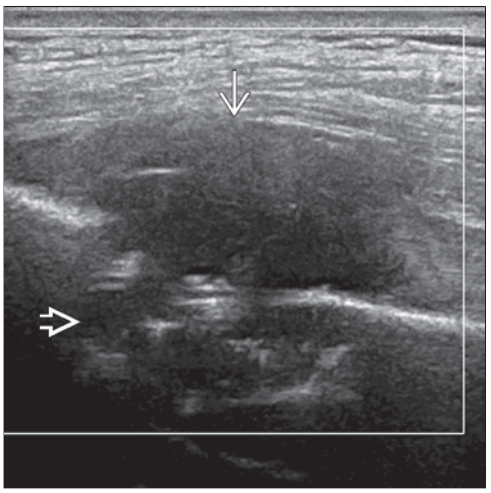




(Left) *Frontal radiograph of the pelvis in a 52-year-old man with myelodysplastic syndrome and recent onset of right hip pain is unremarkable. The patient was referred for ultrasound examination.* ***(Right)*** *Longitudinal oblique ultrasound of the gluteal region (following normal examination of the hip region) shows focal irregular osteolysis of the ilium* ➔ *with a large hypoechoic extraosseous soft tissue component* ➔ *bulging into the gluteal muscle.*

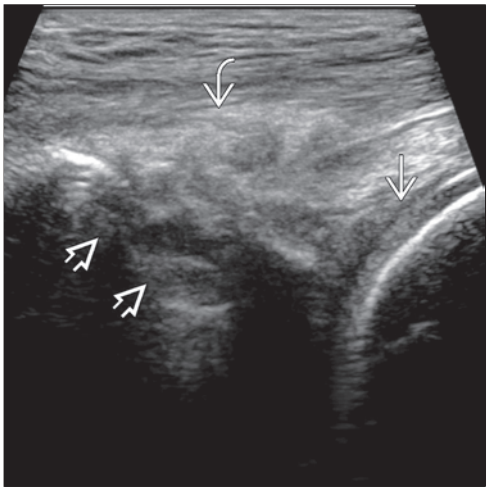
BONE TUMOR

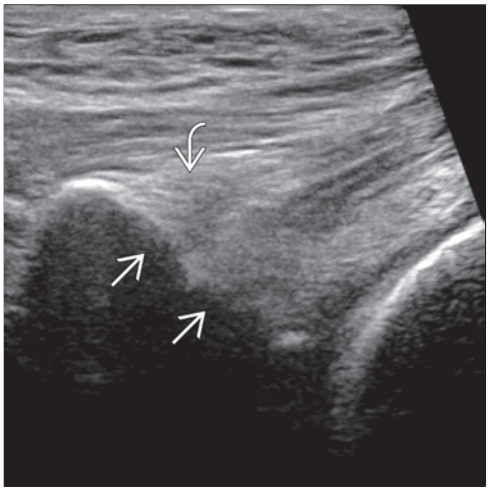
(Left) *Longitudinal oblique color Doppler ultrasound of the same lesion reveals no detectable tumoral or peritumoral hyperemia. This does not preclude the presence of viable tumor tissue. Ultrasound-guided biopsy revealed blastic transformation of preexisting myelodysplastic syndrome.* ***(Right)*** *Axial CECT following ultrasound and biopsy shows the osteolytic tumor in the medial aspect of the right iliac bone adjacent to the sacroiliac joint.*



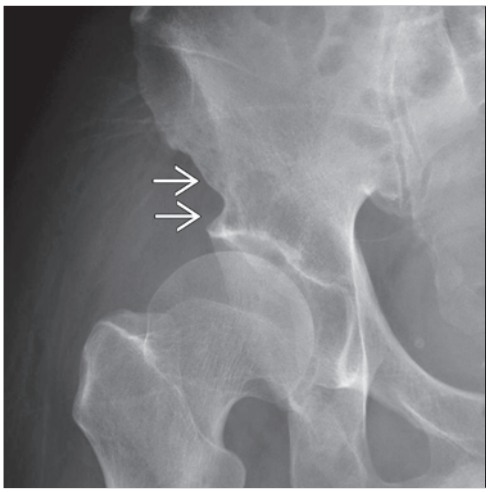


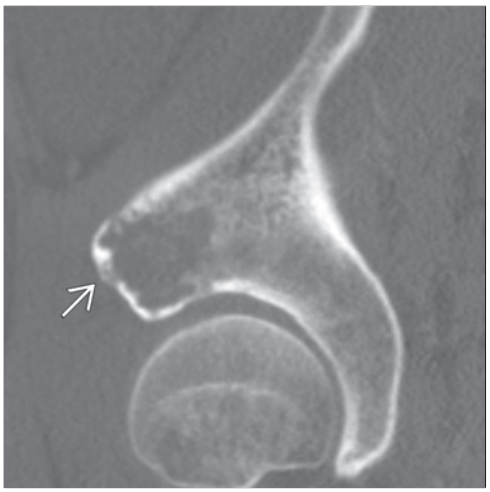
(Left) *Longitudinal ultrasound of the hip in a patient with metastatic lung disease and clinically suspected hip septic arthritis shows irregular osteolysis of the right supraacetabular area and adjacent soft tissue swelling. The hip joint is normal.* ***(Right)*** *Longitudinal ultrasound of the contralateral normal hip in the same patient is shown for comparison. Note the smooth supraacetabular cortical outline providing attachment to the rectus femoris tendon and absence of soft tissue swelling.*



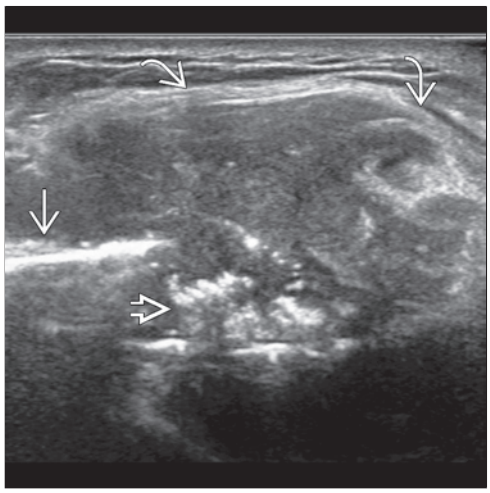


(Left) *Frontal radiograph of the right hip in the same patient subsequently revealed mild hip dysplasia with irregular supraacetabular osteolysis.* ***(Right)*** *Sagittal reformat noncontrast CT in the same patient shows osteolysis at the anterior aspect of the supraacetabular area. Although ultrasound is traditionally not used for investigating bone pathology, it can, in certain instances, provide very helpful information. This painful metastatic deposit was irradiated with good effect.*

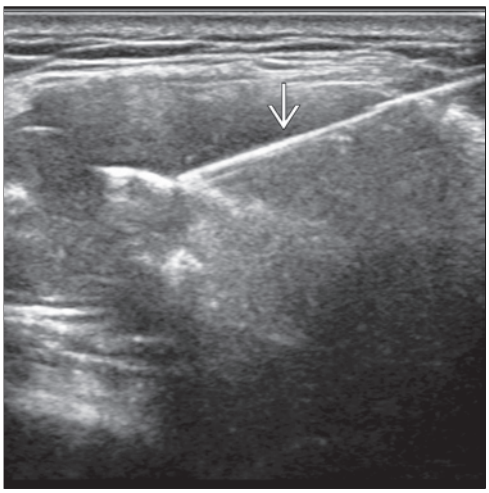


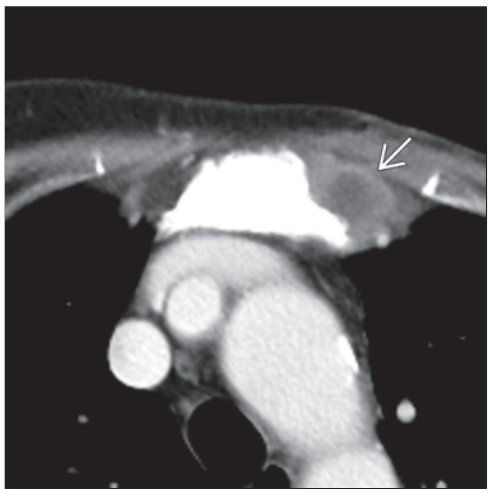




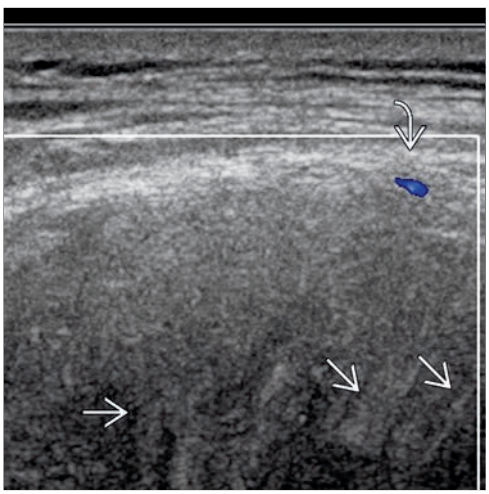


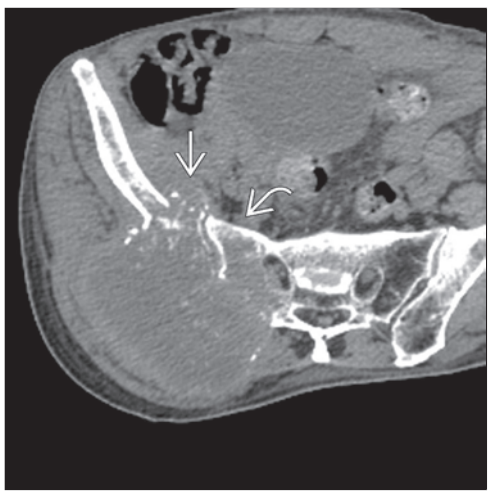
(Left) *Photograph shows a patient with left mastectomy for breast carcinoma 2 years ago and recent onset of sternal swelling* ⇨. ***(Right)*** *Transverse ultrasound of same patient shows irregular osteolysis* ⇨ *on the left side of the sternum* ⇨ *with a large extraosseous soft tissue component* ⇨ *highly suspicious of metastatic deposit. Sternal metastases are common in breast carcinoma and commonly present as a lump due to the superficial location of the sternum.*





(Left) *Transverse ultrasound shows the same patient during percutaneous Tru-Cut needle biopsy* ⇨ *of the sternal tumor. Biopsy tissue revealed metastatic breast carcinoma.* ***(Right)*** *Axial CECT of the same patient in soft window setting shows the metastatic deposit* ⇨ *on the left side of the sternum. Subsequent PET/CT revealed that this was an isolated metastatic deposit. The patient received chemoirradiation. Sternotomy is an alternative treatment option for isolated sternal breast metastases.*





(Left) *Transverse color Doppler ultrasound in a patient with clinically suspected soft tissue buttock sarcoma shows a large soft tissue mass with radiating echogenic spicules* ⇨. *These spicules suggest a bony origin, which was confirmed by 7.5 MHz ultrasound imaging (not shown). Little demonstrable tumoral hyperemia* ⇨ *is present.* ***(Right)*** *Axial noncontrast CT shows a large tumor mass arising from the iliac* ⇨ *and sacral* ⇨ *bones. Histology revealed primitive neuroectodermal tumor.*

LOCAL TUMOR RECURRENCE

Key Facts

Terminology
- Local recurrence of tumor following initial planned complete tumor resection
  - If original tumor was not completely resected, this is residual tumor rather than recurrence

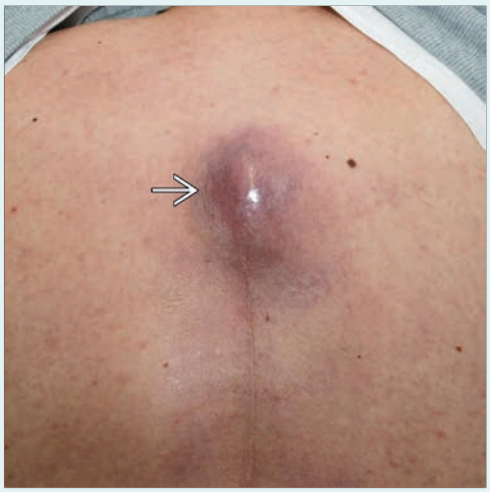
Imaging
- Ultrasound is as sensitive/specific as MR for detecting bone or soft tissue recurrence
- Presence of discrete soft tissue mass is best diagnostic clue
  - Variable echogenicity and vascularity of recurrent tumor, but mirrors that of primary tumor
- Examine entire section of limb from which primary tumor was resected
- Consider likelihood of postoperative, nontumoral mass
- For bone tumor, correlate with radiographs if any bone abnormality is detected
- Routinely examine regional lymph nodes
- Arrange either ultrasound follow-up or ultrasound-guided biopsy of any suspicious mass lesion

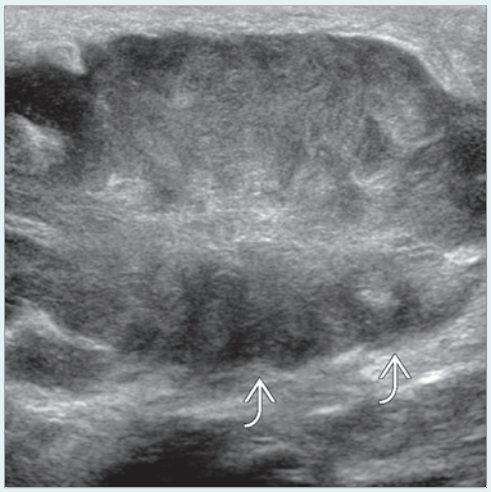
Top Differential Diagnoses
- Postoperative seroma/hematoma
- Postoperative fibrosis/granulation tissue
- Reactive bone change at resection margin

Pathology
- Several factors may govern risk of recurrence
  - Positive surgical margins, tumor depth, size, and histologic grade

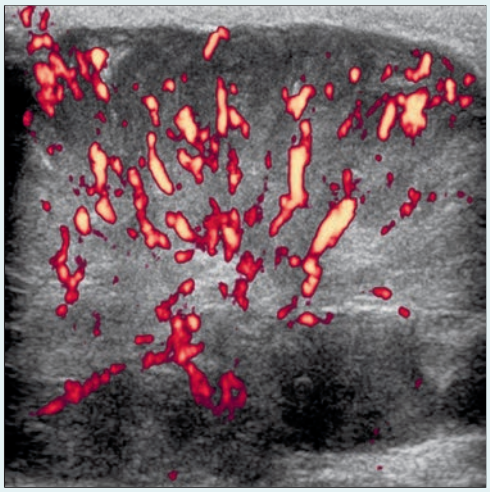
Clinical Issues
- Most local recurrences occur in first 3 years after diagnosis
- Early detection of local recurrence helps avoid extensive second surgery or amputation

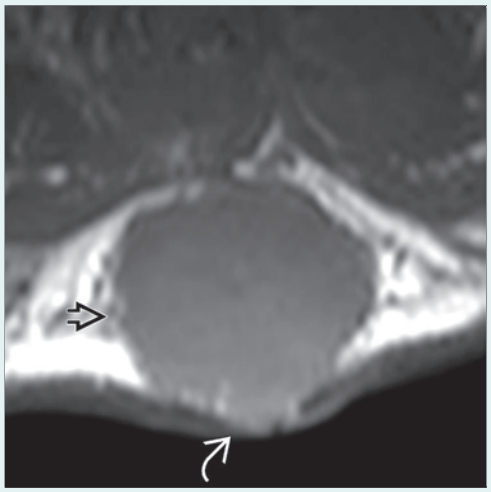
(Left) *Clinical photograph shows a patient with myeloma of the spine treated with excision and posterior spinal fusion 6 months earlier. A nodule at the upper end of the scar in the dorsal region became apparent 3 weeks earlier.* ***(Right)*** *Longitudinal ultrasound of the dorsal region in the same patient shows a heterogeneous soft tissue mass at the site of the clinically palpable nodule. The margins are slightly irregular. Features are highly suspicious for local recurrence.*





(Left) *Longitudinal power Doppler ultrasound of the same tumor shows severe hypervascularity present throughout the mass.* ***(Right)*** *Transverse T1WI MR of the same tumor shows a large recurrent tumor occupying the subcutaneous tissue of the upper end of the scar with bulging skin contour. The dermis is also infiltrated. Ultrasound-guided biopsy for histology confirmed extraosseous myeloma.*





LOCAL TUMOR RECURRENCE

TERMINOLOGY

Abbreviations
- Soft tissue sarcoma (STS)

Definitions
- Local recurrence of tumor following initial planned complete tumor resection
  - If original tumor was not completely resected, this is residual tumor rather than recurrence

IMAGING

General Features
- Best diagnostic clue
  - Presence of discrete soft tissue mass
- Location
  - Most common along tract of tumor excision
    - Anywhere under surgical scar area
  - Local recurrences from superficial tumor commonly occur in muscle layer exposed at time of initial tumor resection
  - Superficial recurrences from deep tumors are generally due to contamination along tract
    - Seeding along tract is much more common with open biopsy
    - Very uncommon with closed image-guided percutaneous biopsy
      - Especially when coaxial system is used as this minimizes any likelihood of inadvertent tumor deposition along tract
- Size
  - Larger in deeper lesions due to later presentation
- Morphology
  - Mirrors that of primary tumor
    - All malignant bone and soft tissue tumors have propensity for recurrence
    - Some benign bone and soft tissue tumors have propensity for recurrence
      - Fibromatosis
      - Giant cell tumor of bone

Ultrasonographic Findings
- **Soft tissue recurrence**
- Presence of discrete soft tissue mass at surgical site is best diagnostic clue
  - Hampered by postradiotherapy, postsurgical fibrosis, and disruption of normal anatomical planes
  - Alongside surgical scar and along open biopsy tract are most common sites for recurrence
    - Rare following image-guided percutaneous biopsy
- Variable echogenicity and vascularity of recurrent tumor, but mirrors that of primary tumor
  - Hypoechoic, hyperemic mass with foci of mineralization for osteosarcoma primary
  - Hyperechoic, nonhyperemic tumor without mineralization for liposarcoma primary
  - Myxoid tissue: Well-defined, intratumoral anechoic or hypoechoic areas
  - Calcification: Discrete intratumoral echogenic foci with acoustic shadowing
  - Hemorrhage: Ill-defined intratumoral echogenic areas with acoustic enhancement; fluid levels
  - Usually hypervascular with disorganized vascular pattern on color Doppler imaging
- Associated abnormality
  - Adjacent bone erosion or periosteal reaction
  - ± regional nodal metastasis (not uncommon with recurrent tumor)
- **Bone tumor recurrence**
- Ultrasound is also very useful at detecting bone tumor recurrence
- Most bone tumor recurrences occur in soft tissue and not in bone
- Most recurrences lie close to prosthetic or allograft implant
  - Ultrasound is not affected by metallic artifact
- Discrete soft tissue mass is best diagnostic clue
  - ± association with underlying bony erosion
  - Echogenicity and matrix tumor characteristics mirror those of primary tumor
    - Same characteristics of primary bone tumor (e.g., matrix mineralization in osteosarcoma)
  - Regional metastatic lymphadenopathy is much more common than with primary bone tumor
  - If tumor clearly originates from bone, metachronous malignancy should be considered, especially for osteosarcoma

MR Findings
- T1WI
  - Presence of discrete, enhancing soft tissue mass
  - Signal intensity pattern of recurrence is similar to that of primary tumor
  - Sensitivity 83%; specificity 93%
- T2WI FS
  - Discrete high signal intensity lesion with mass effect
  - Moderate perilesional edema

Imaging Recommendations
- Best imaging tool
  - Ultrasound, as it is easily available, does not require contrast injection and is not subject to metallic artifact
    - Ultrasound is as sensitive/specific as MR for detecting bone or soft tissue recurrence
    - Allows ready assessment of regional lymph nodes
    - Ultrasound-guided biopsy provides definitive proof of recurrence
  - For high-grade bone or soft tissue sarcoma, follow-up at 3 months after surgery, then every 6 months for 2 years, then yearly thereafter for 5 years
  - For low-grade bone or soft tissue sarcoma, follow-up at 6 months after surgery, then yearly thereafter for 3 years
  - However, still not clear whether routine surveillance actually improves survival
- Protocol advice
  - Same protocol is used for both bone and soft tissue recurrence
  - Examine entire section of limb from which primary tumor was resected (e.g., thigh, leg, arm, or forearm)
  - Use a parallel series of longitudinal sweeps (with transducer aligned transversely) from proximal to distal along affected limb segment

LOCAL TUMOR RECURRENCE

- Examine patient in both supine and prone positions to ensure that entire circumference of operated segment of limb is examined
- Look for any discrete soft tissue mass
- Consider likelihood of postoperative, nontumoral masses
  - Chronic collection
  - Organizing hematoma
  - Postoperative fibrosis
  - Localized fat hypertrophy to replace resected muscle
  - Retracted transected muscle belly
  - Reactive changes at bone resection margin
- For bone tumor, correlate with radiographs if any bone abnormality is detected
- Routinely examine regional lymph nodes
  - Fine-needle aspiration for cytology if lymph nodes suspicious
- Either ultrasound follow-up or ultrasound-guided biopsy of suspicious mass lesion
  - Sample solid component of suspicious tissue
  - 16-gauge or 14-gauge Tru-Cut core biopsy with coaxial system is necessary for tissue typing and histological grading

DIFFERENTIAL DIAGNOSIS

Postoperative Seroma/Hematoma
- Usually more cystic in appearance, avascular
- Less mass effect
- Tends to remain static or regress on serial imaging

Postoperative Fibrosis/Granulation Tissue
- Less mass effect, usually less well defined and more irregular
- Occurs at and tracks along surgical tract
- Does not progress on serial follow-up

Reactive Bone Change at Resection Margin
- Occurs at prosthetic/native bone, allograft/native bone
- New bone formation and localized soft tissue thickening
- Little, if any, mass effect
- Correlate any abnormal ultrasound appearances with radiograph
  - Radiography is very helpful in sorting out suspicious bone areas seen on ultrasound

PATHOLOGY

General Features
- Etiology
  - Several factors likely to be contributory
    - Unplanned resection
    - Histological grade of tumor

Gross Pathologic & Surgical Features
- Pathology mirrors that of primary tumor
  - Usually similar grade to primary tumor
  - Infrequently, recurrence may have more aggressive histological features than primary tumor

CLINICAL ISSUES

Presentation
- Most common signs/symptoms
  - New lump at site of previous surgery
    - Clinical detection of recurrence can be hampered by scar tissue or deep location of recurrence
      - Especially true for irradiated surgical beds as soft tissue is scarred and indurated
- Other signs/symptoms
  - Pain from bone tumor recurrence
  - Weight loss and other constitutional symptoms probably reflect systemic metastatic disease

Demographics
- Epidemiology
  - 6-14% of patients develop local recurrence after soft tissue sarcoma treatment
  - Greater risk of recurrence for
    - High-grade > low-grade tumors
    - Larger size of primary tumor
    - Positive histological margins with postoperative radiotherapy associated with risk of recurrence is 5.9x that of tumor with clear resection margins
    - Patients with treated local recurrence have higher likelihood of subsequent local recurrence

Natural History & Prognosis
- Most local recurrences occur in first 3 years after diagnosis
- Local recurrence requires additional surgery, radiotherapy, or amputation
  - Early detection of local recurrence helps avoid extensive surgery or amputation
- Local recurrence of malignant tumors is associated with overall poor prognosis (2-year survival rate of 50-70%)

Treatment
- Well-planned re-resection in specialized tumor center
  - ± radiotherapy ± chemotherapy
- Radiotherapy is very useful in resected tumor with positive margins
  - Likelihood of radioresistance is high in patients with recurrence and prior radiotherapy treatment
  - Rate of wound complications increases with radiotherapy
- Amputation

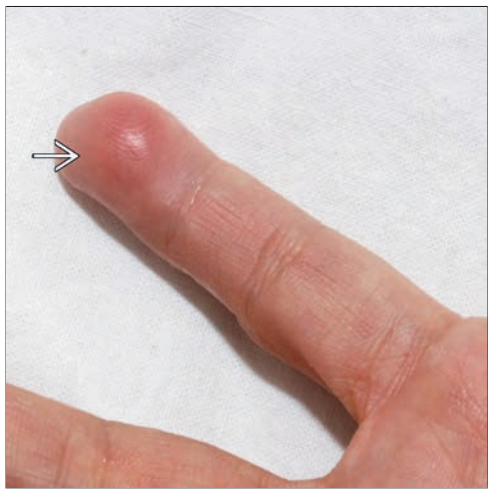
DIAGNOSTIC CHECKLIST

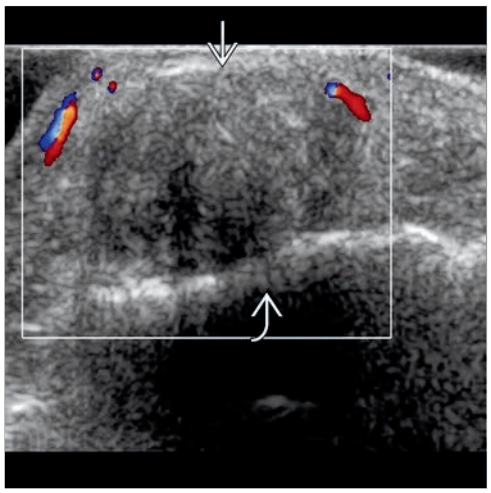
Consider
- Regional nodal involvement

Image Interpretation Pearls
- Look for discrete soft tissue mass

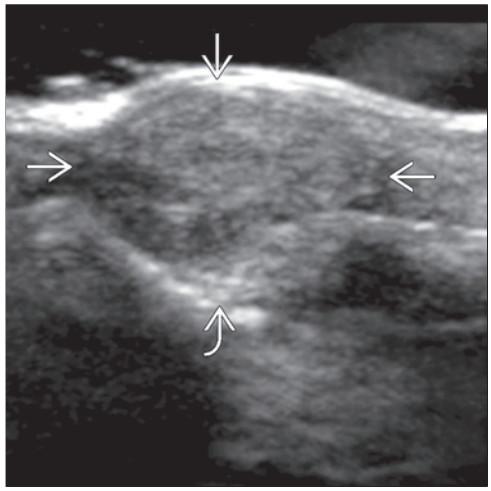
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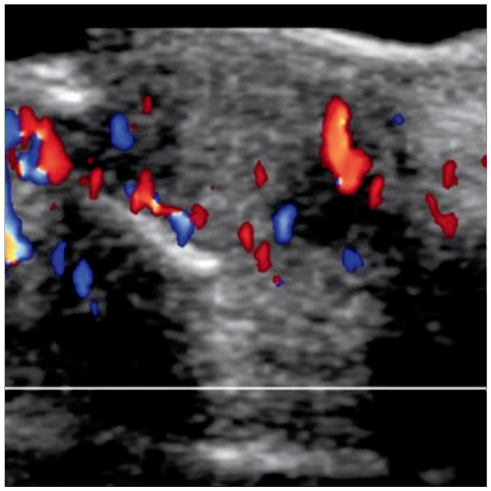
1. Sawamura C et al: How long should we follow patients with soft tissue sarcomas? Clin Orthop Relat Res. 472(3):842-8, 2014
2. Biau DJ et al: Local recurrence of localized soft tissue sarcoma: a new look at old predictors. Cancer. 118(23):5867-77, 2012



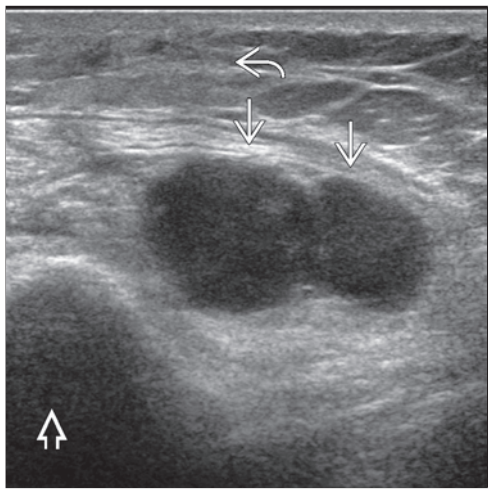


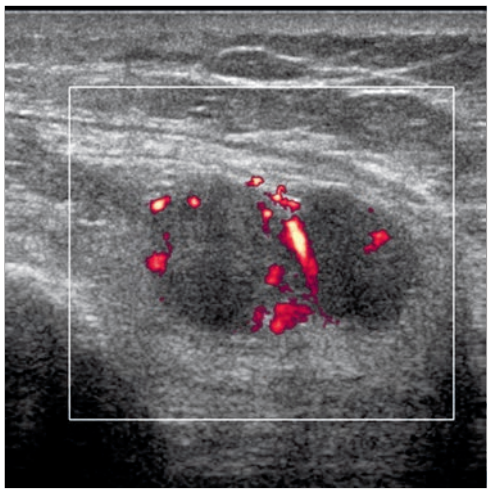
(Left) *Clinical photograph shows a patient with swelling ➔ at the tip of the little finger, which had been slowly growing for 1 year.* ***(Right)*** *Longitudinal color Doppler ultrasound of the same patient shows a well-defined, hypovascular mass ➔ at the tip of the distal phalanx with mild, posterior bony scalloping ➔. Histology revealed a giant cell tumor. The tumor was excised.*





(Left) *Longitudinal ultrasound of the same finger 3 years later shows a locally recurrent tumor ➔ with more severe bony scalloping ➔. The bony scalloping was likely the result of the previous surgery rather than progressive tumor-related osteolysis.* ***(Right)*** *Longitudinal color Doppler ultrasound of the same tumor shows moderate hyperemia. In most cases, local recurrence will have similar ultrasound characteristics to the original tumor.*

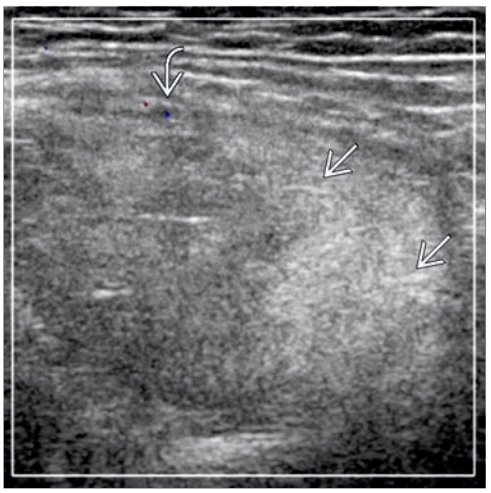


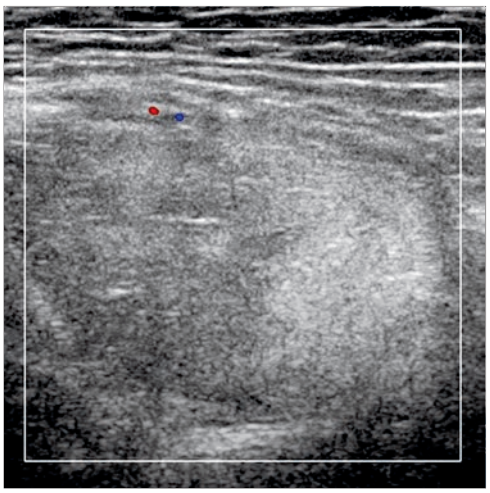


(Left) *Transverse ultrasound of the lateral thigh in a patient with high-grade malignant fibrous histiocytoma of the thigh excised 1 year earlier shows a well-defined hypoechoic mass ➔ deep to the surgical scar ➔ compatible with local recurrence. The femur is shown ➔. The surgical scar is seen as echogenic subcutaneous fat rather than hypoechoic fibrous tissue.* ***(Right)*** *Transverse power Doppler ultrasound of the same tumor shows moderate tumoral hyperemia. A discrete mass is the defining characteristic of local recurrence.*

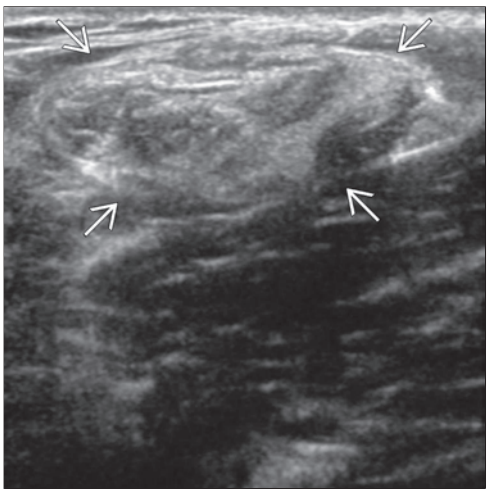
LOCAL TUMOR RECURRENCE

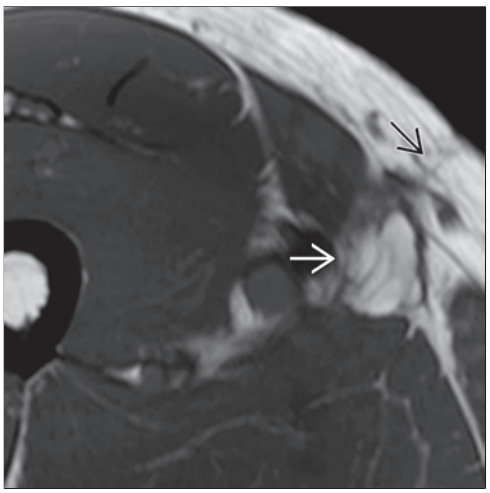
(Left) *Longitudinal color Doppler ultrasound shows a large, well-defined heterogeneous, mildly echogenic mass present within the vastus medialis muscle. There are some faint, thin, linear striations present. **(Right)** Transverse color Doppler ultrasound of the same tumor confirms no significant vascularity within the tumor. The appearances are highly suspicious of an intramuscular liposarcoma, which was confirmed by percutaneous biopsy for histology.*



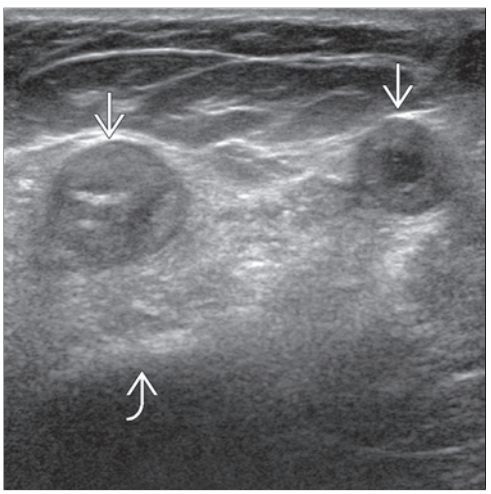


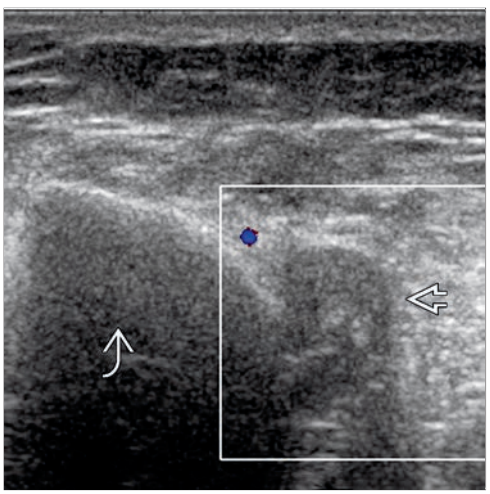
(Left) *Longitudinal ultrasound of the same region in the same patient 5 years later shows a discrete, largely echogenic mass with well-defined border. Overall, features are highly suspicious of recurrent liposarcoma with a fatty tumor developing at the site of tumor recurrence. **(Right)** Transverse T1WI MR of the same tumor shows a fatty tumor on the medial aspect of the thigh just deep to the surgical scar. Histology confirmed liposarcoma recurrence.*

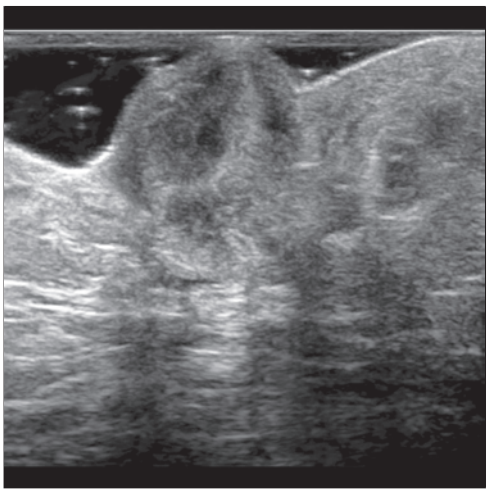


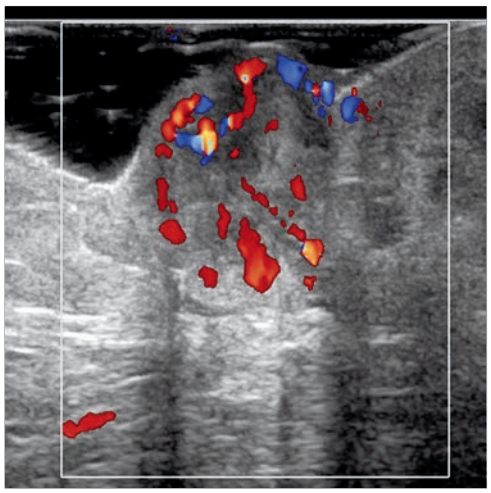


(Left) *Transverse ultrasound in a patient with above-elbow amputation due to epithelioid sarcoma 3 years earlier shows 2 well-defined hypoechoic nodules within the arm stump consistent with recurrence and confirmed by histology. The humerus is normal at this level. **(Right)** Transverse color Doppler ultrasound in the same patient shows another recurrent nodule alongside the humerus. No hyperemia is present. Multiple tumor recurrences may be present in the same patient.*

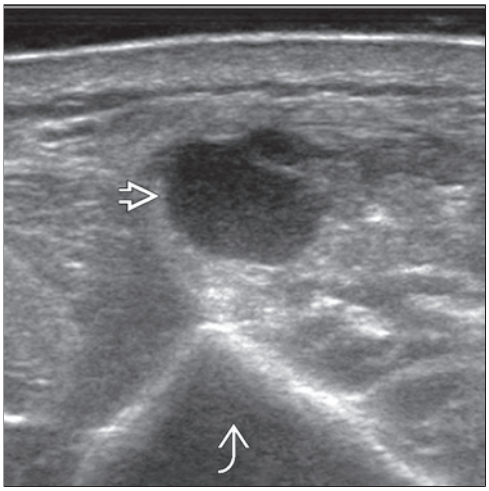


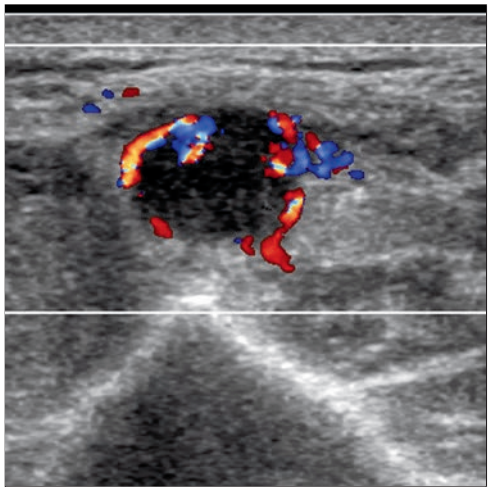




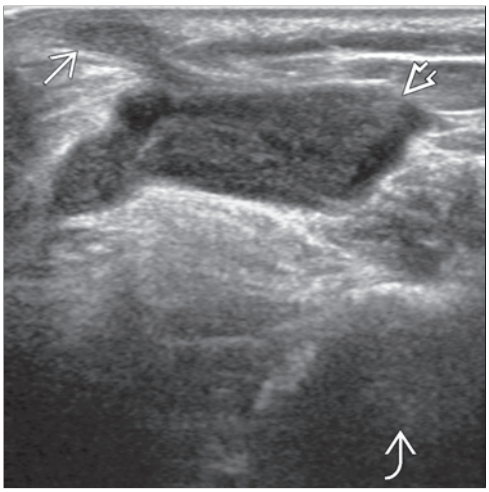


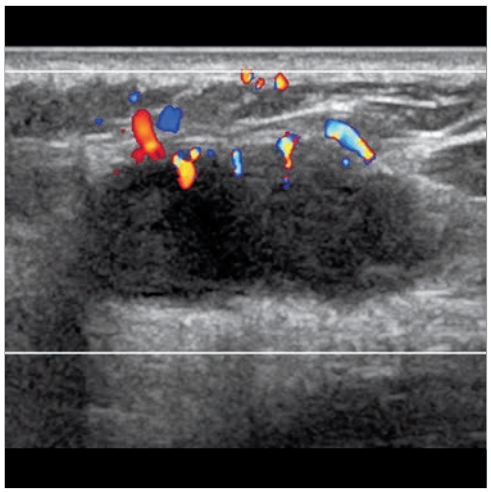
(Left) *Longitudinal ultrasound in a patient with low-grade malignant fibrous histiocytoma who had undergone wide local excision followed by radiotherapy following an initial relapse 2 years earlier; the patient presented with a new mass at the lateral end of the scar. Ultrasound shows a quite well-defined mass confined to the cutaneous and subcutaneous tissues.* ***(Right)*** *Longitudinal color Doppler ultrasound shows moderate tumoral hyperemia. Percutaneous biopsy for histology confirmed local recurrence.*





(Left) *Transverse ultrasound of the forearm in a patient with subcutaneous dermatofibrosarcoma protuberans resected 3 years earlier shows a discrete hypoechoic nodule within the extensor carpi ulnaris muscle consistent with recurrence alongside the ulnar shaft.* ***(Right)*** *Transverse color Doppler ultrasound of the same tumor shows moderate peripheral hyperemia. Histology confirmed recurrence. Recurrences from subcutaneous tumors often occur within muscle.*

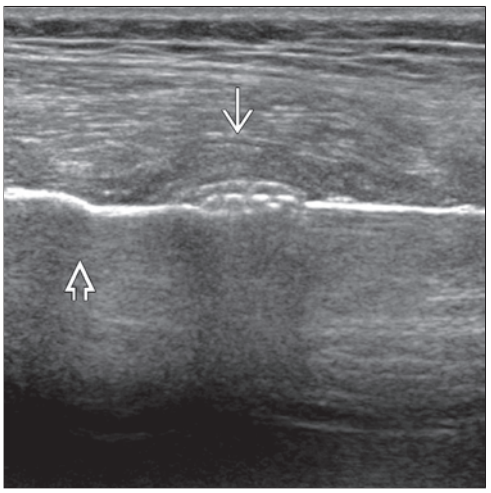


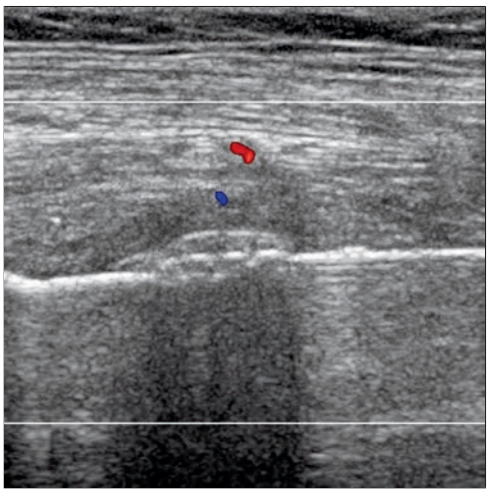


(Left) *Transverse ultrasound of the arm in a patient with prior excision of fibromatosis shows fibrosis deep to the cutaneous scar. A well-defined, uniformly hypoechoic mass is present deep to the investing fascia consistent with fibromatosis recurrence. The humerus is normal.* ***(Right)*** *Longitudinal color Doppler ultrasound shows mild peripheral hyperemia. Histology confirmed fibromatosis recurrence. Particular benign tumors such as fibromatosis and giant cell tumor have a propensity to recur.*

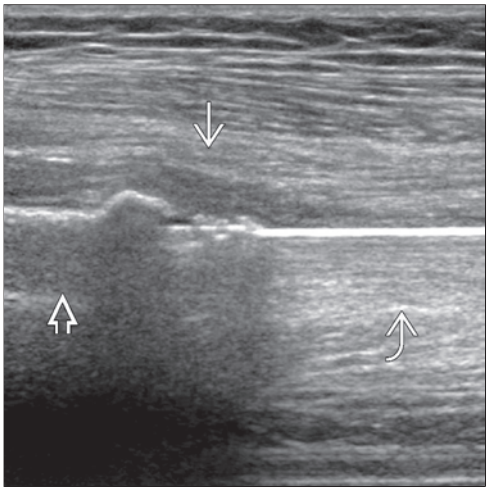
LOCAL TUMOR RECURRENCE

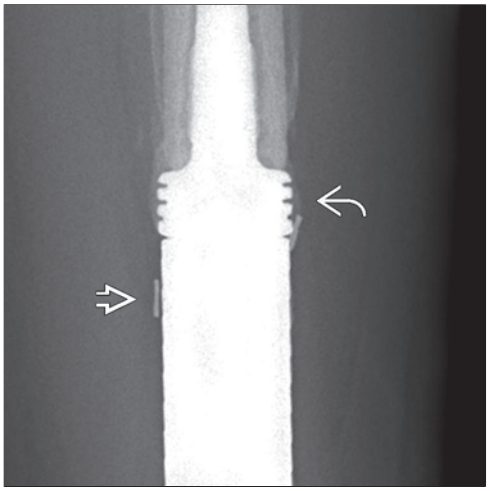
(Left) *Longitudinal surveillance ultrasound in a patient with high-grade femoral osteosarcoma at 6 months post resection shows soft tissue thickening and apparent new bone formation alongside the prosthesis just distal to the bone:prosthesis junction* ***(Right)*** *Longitudinal color Doppler ultrasound of the same area shows mild hyperemia.*



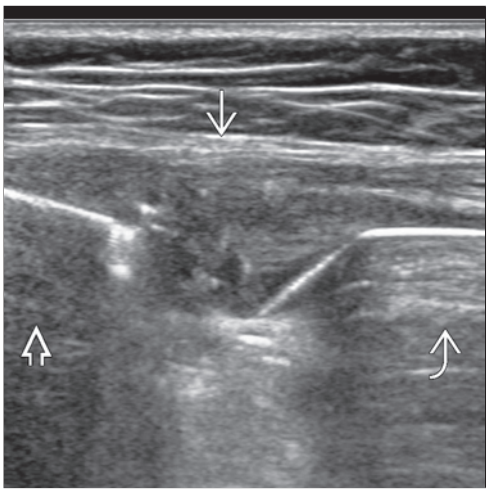


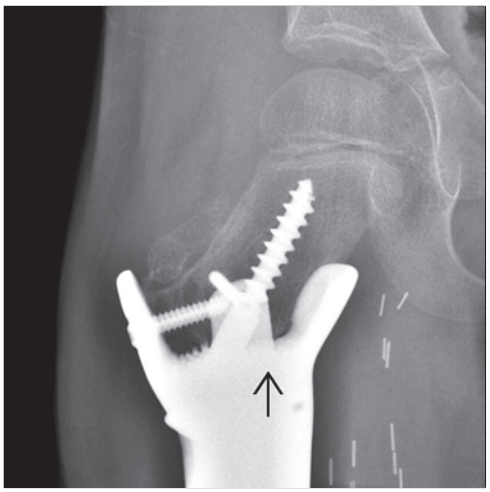
(Left) *Longitudinal ultrasound of the same patient also shows some reactive new bone formation with soft tissue thickening at the interface between the prosthesis and bone.* ***(Right)*** *Frontal radiograph of the bone:prosthesis junction in the same patient provides an explanation for the suspicious ultrasound appearances due to surgical clips and reactive bone change with no tumor recurrence. Follow-up ultrasound 4 weeks later showed no progression.*

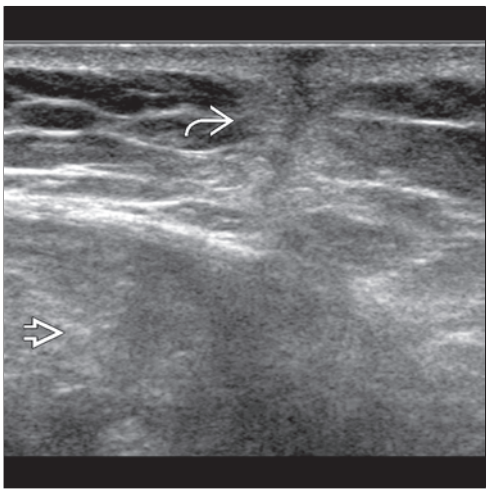


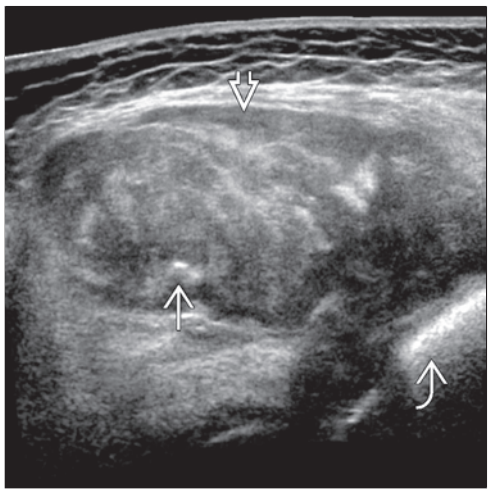


(Left) *Longitudinal surveillance ultrasound of the proximal thigh in a young boy with osteosarcoma resected 1 year earlier shows an apparent defect at the interface of the bone and prosthesis with overlying soft tissue thickening.* ***(Right)*** *Frontal radiograph of the same area provides an explanation for ultrasound findings, which are exactly as expected due to the design of the prosthesis. No recurrence was reported, and a follow-up ultrasound 2 months later showed no progression.*

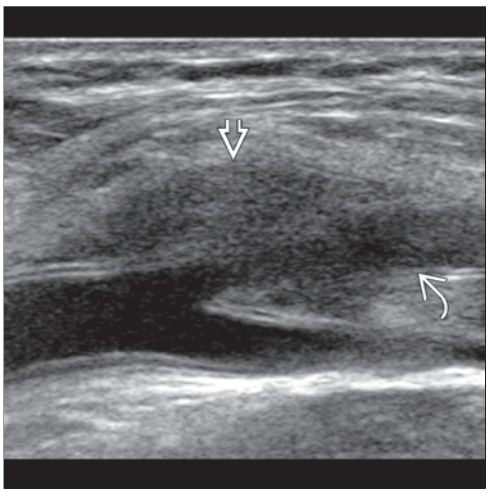


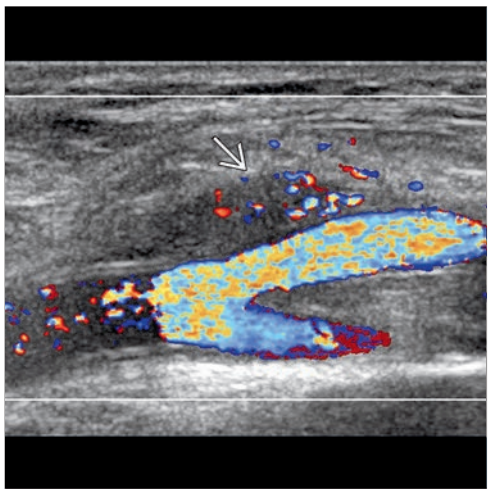




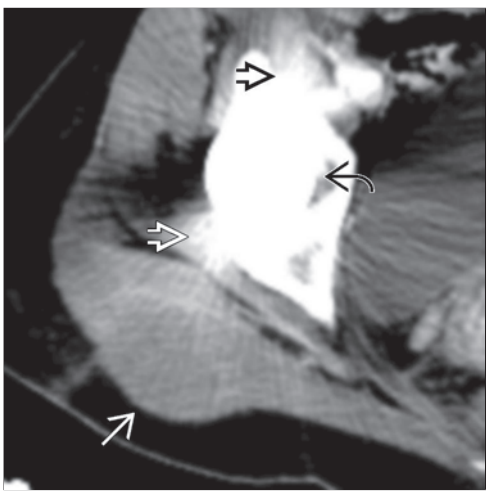


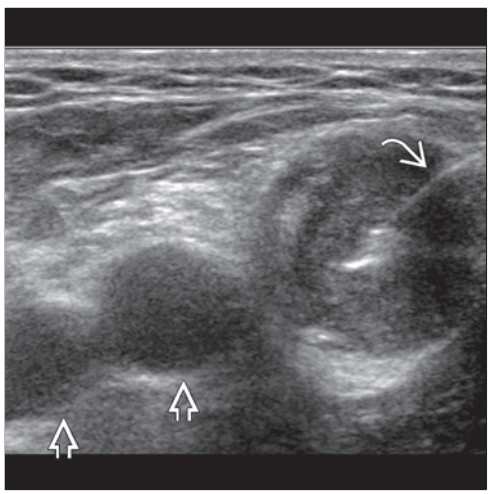
(Left) *Transverse ultrasound of the buttock in a patient with proximal femoral chondrosarcoma resected 1 year earlier shows a large, hypoechoic tumor recurrence deep to the surgical scar.* ***(Right)*** *Transverse larger and extended field-of-view ultrasound of the same tumor shows the large, slightly heterogeneous tumor recurrence just above the trochanteric region of the prosthesis. There is some echogenic matrix calcification.*





(Left) *Longitudinal ultrasound of the anterior groin in the same patient shows regional adenopathy with metastatic infiltration of the superficial femoral artery close to the bifurcation.* ***(Right)*** *Longitudinal color Doppler ultrasound of the same tumor shows mild tumoral hyperemia and arterial patency.*

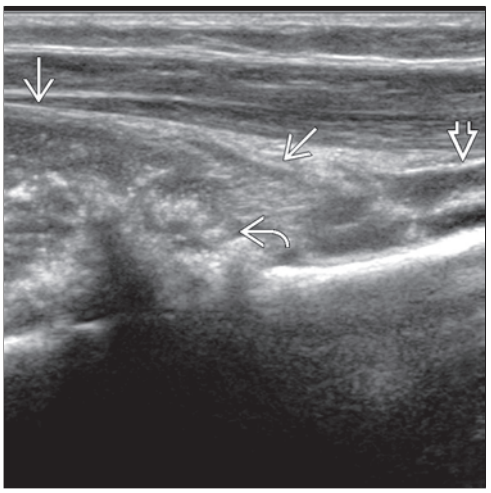


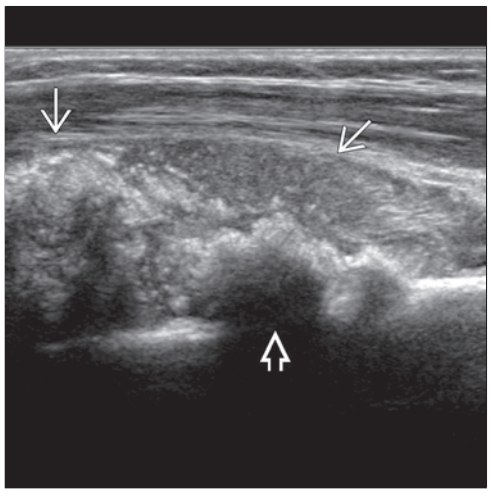


(Left) *Axial CECT of the same patient shows tumor recurrence posterior to the prosthesis, though not as well seen as on ultrasound. The metastatic nodes in the inguinal and external iliac region are not well seen on CT due to metallic artifact.* ***(Right)*** *Transverse ultrasound of the same patient during needle biopsy of a metastatic-type inguinal node shows the femoral vessels medial to the enlarged node. Histology confirmed metastatic chondrosarcoma.*

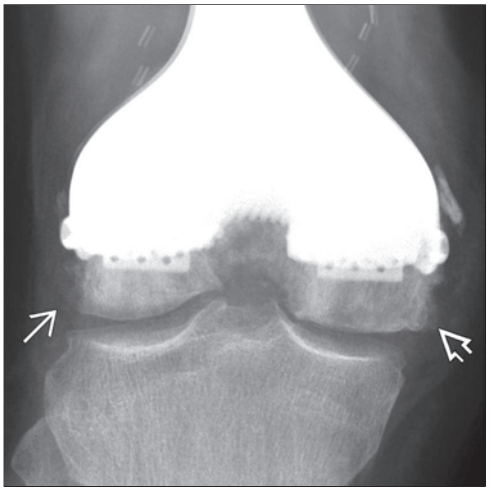
LOCAL TUMOR RECURRENCE

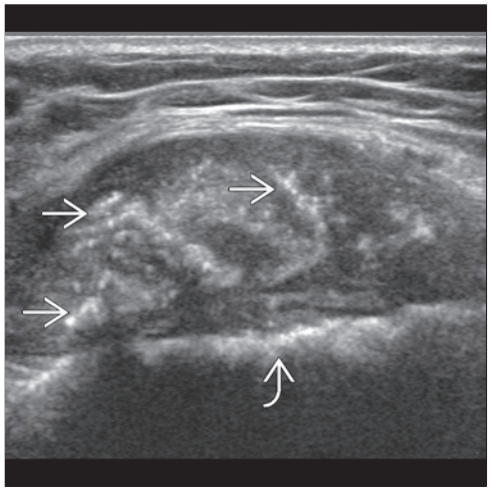
(Left) *Longitudinal ultrasound in a patient with osteosarcoma of the humerus excised 10 years earlier shows a large, osteosarcoma-like mass with new bone formation arising from the ipsilateral radial diaphysis. Severe periosteal thickening extends well beyond the tumor margin.* ***(Right)*** *Longitudinal ultrasound of the same tumor shows sunburst-like new bone formation within the tumor. This tumor is due to metachronous osteosarcoma rather than local recurrence.*



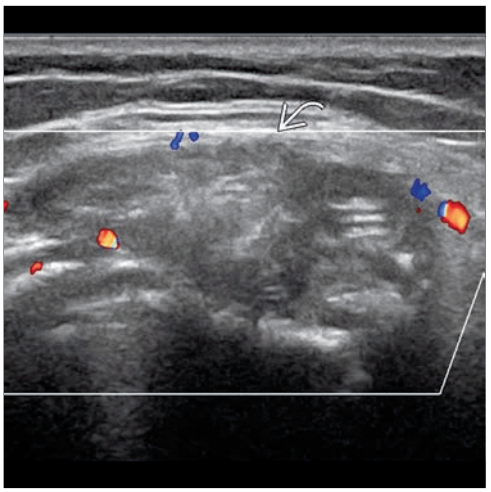


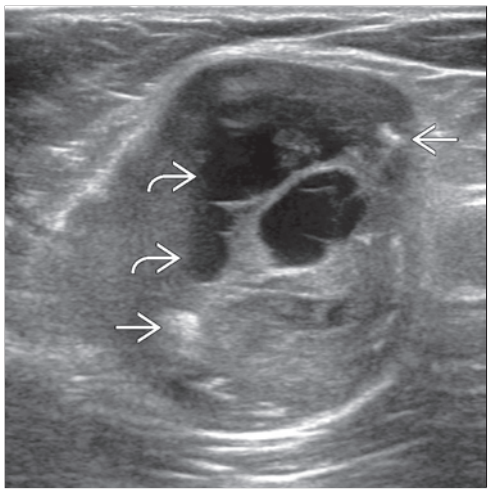
(Left) *Frontal radiograph of a patient with osteosarcoma resected 3 years earlier and increasing knee swelling for 2 months shows permeative osteolysis of both the medial and lateral femoral condyles, highly suspicious of tumor recurrence.* ***(Right)*** *Transverse ultrasound in the same patient shows a large tumor recurrence alongside the medial femoral condyle with matrix mineralization consistent with osteosarcoma recurrence.*

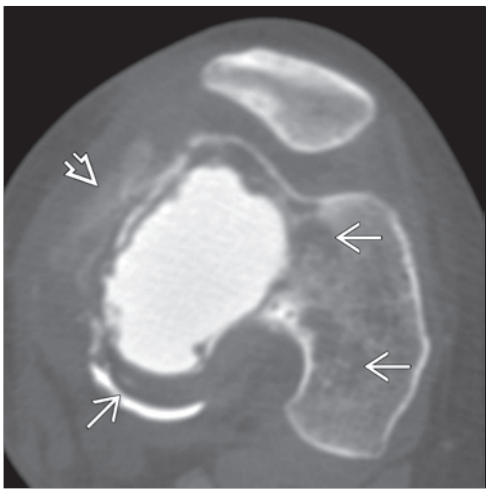


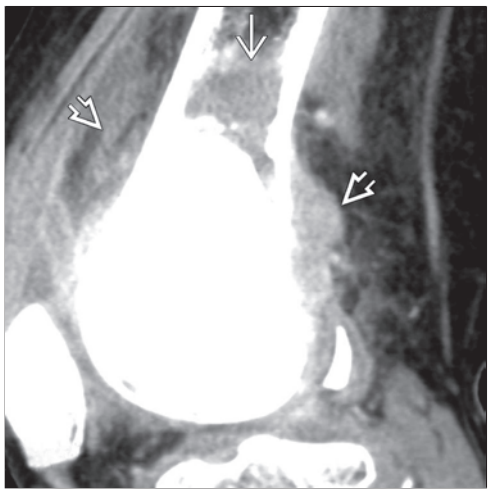


(Left) *Transverse color Doppler ultrasound of the same area as previous image shows mild peripheral hyperemia of the recurrent tumor.* ***(Right)*** *Transverse ultrasound of the ipsilateral groin in the same patient shows a soft tissue mass with cystic and calcific changes compatible with a metastatic node. Mineralization is common in metastatic osteosarcoma. Nodal metastases in bone sarcoma recurrence are not uncommon, though are rare on initial presentation.*

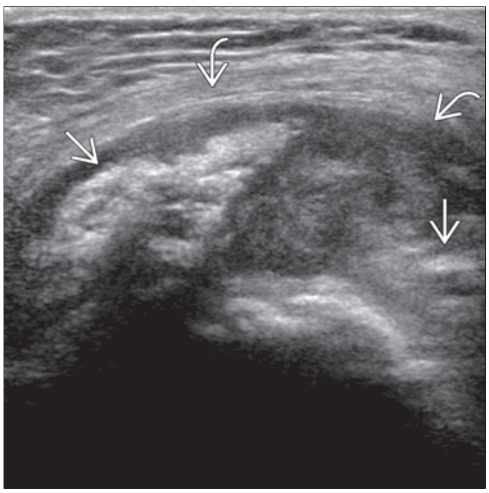


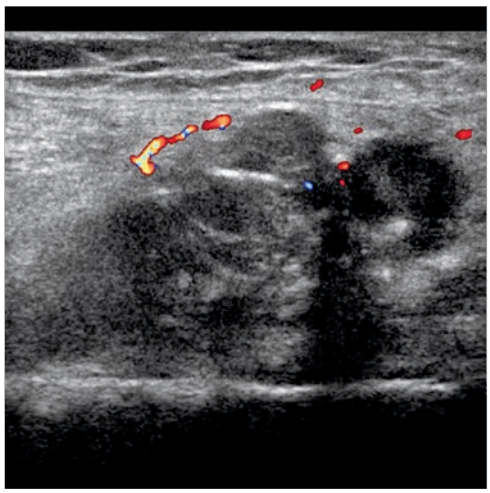




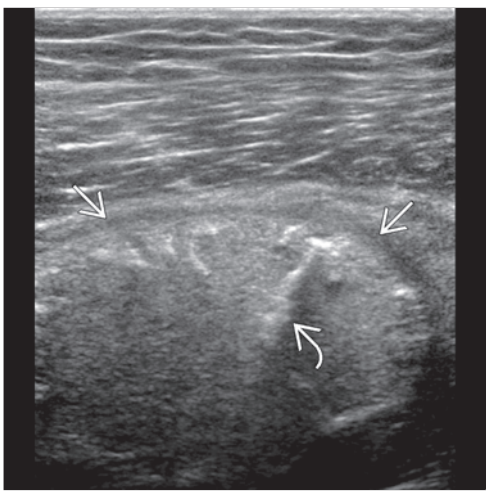


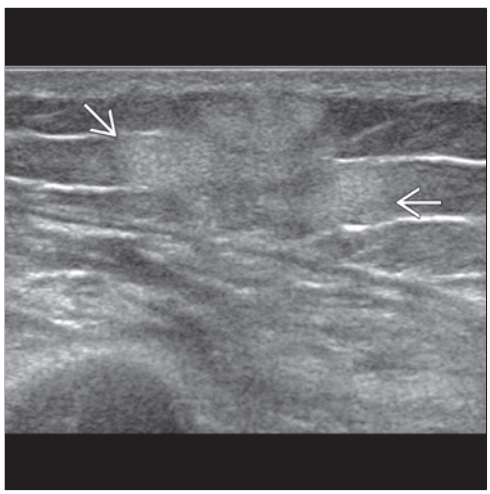
(Left) *Axial noncontrast CT in a patient 1 year following resection of initially suspected giant cell tumor shows osteolysis due to tumor recurrence around the bone cement* ➔ *with new bone formation* ➔ *in the soft tissue alongside the lateral femoral condyle.* ***(Right)*** *Sagittal CT reconstruction in the same patient shows severe intramedullary* ➔ *and juxtacortical* ➔ *tumor recurrence.*



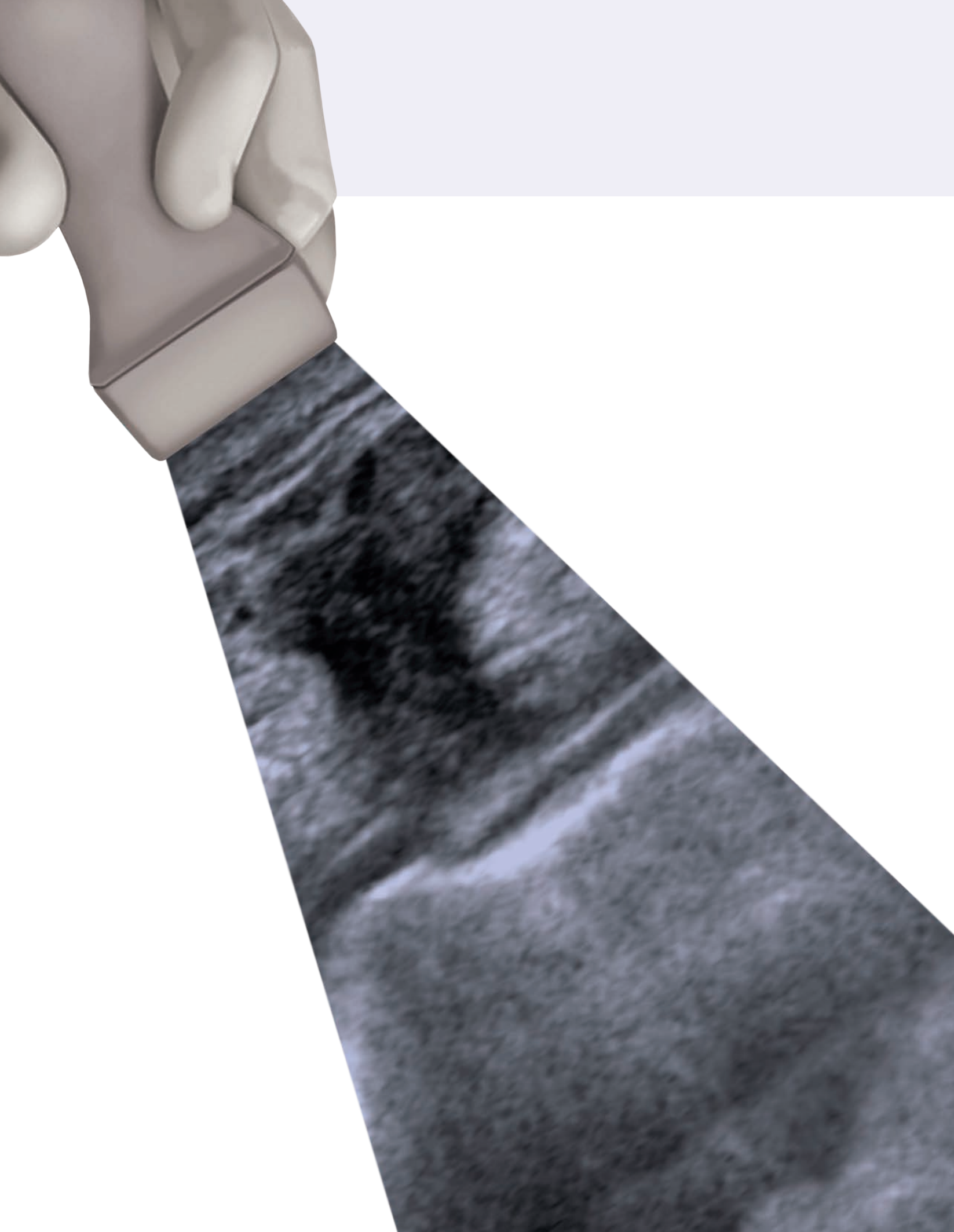


(Left) *Transverse ultrasound of the same patient as previous image shows prominent new bone formation* ➔ *within the large hypoechoic area of extraosseous tumor recurrence* ➔. ***(Right)*** *Longitudinal color Doppler ultrasound of the same patient shows mild hyperemia of this tissue with additional small areas of calcification. This aggressive recurrence along with new bone formation prompted review and reclassification of the initial histology from giant cell tumor to giant cell tumor variant of osteosarcoma.*





(Left) *Longitudinal ultrasound shows a large soft tissue osteosarcoma recurrence* ➔ *with matrix mineralization* ➔. ***(Right)*** *Transverse ultrasound of a patient with high-grade soft tissue sarcoma excised 3 months earlier who developed recent thigh swelling remote from the resection site. Ultrasound shows a subcutaneous echogenic area* ➔ *with no mass effect or other suspicious features such as hyperemia. A diagnosis of subcutaneous fat necrosis was made. Follow-up ultrasound 2 months later showed moderate resolution, which is consistent with this diagnosis.*



SECTION 9

Hernia

Abdominal Wall Hernia **II**-9-2
Groin Hernia **II**-9-10

ABDOMINAL WALL HERNIA

Key Facts

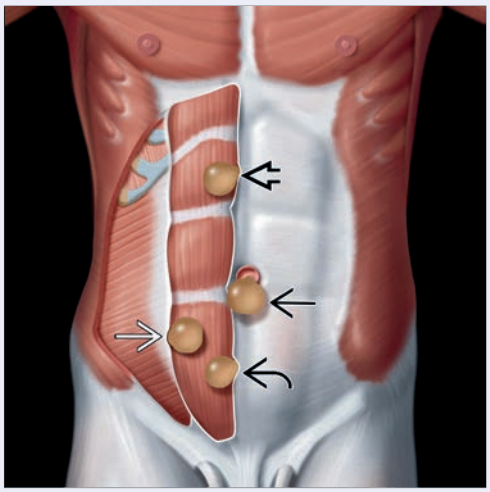
Clinical Issues

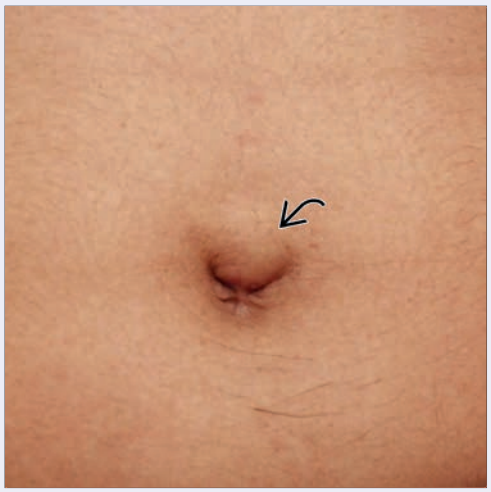
- Tissue protruding though defect in abdominal wall
- Midline hernias
  - Epigastric: Usually small
  - Umbilical: In children
  - Paraumbilical: In adults
  - Hypogastric: Rare
- Lateral hernias
  - Spigelian: Defect in transversus abdominis aponeurosis lateral to rectus sheath (linea semilunaris)
  - Lumbar: Occur in 2 areas of potential weakness in flank
  - Superior lumbar triangle (Grynfeltt hernia) with erector spinae medially, 12th rib superiorly, and internal oblique muscle laterally
  - Inferior lumbar triangle (Petit hernia) with latissimus dorsi muscle medially, iliac crest inferiorly, and external oblique muscle laterally

Diagnostic Checklist

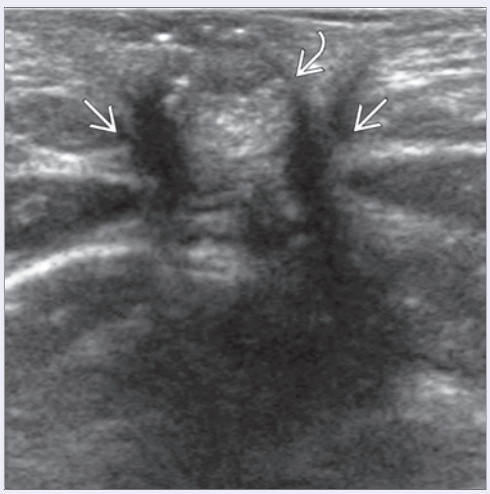
- Determine nature of herniated content (omentum, bowel), site/size of abdominal wall defect
  - Omental fat: Echogenic/hypoechoic tissue without peristalsis on real-time ultrasound
  - Bowel: Visible peristalsis, "target" echo pattern with strong central echoes due to air in lumen
  - Routinely use Valsalva maneuver ± examination in standing position
- Observe for reducibility and consider whether it is obstructed or strangulated (if bowel content present)
  - These complications are uncommon in noninguinal abdominal wall hernias

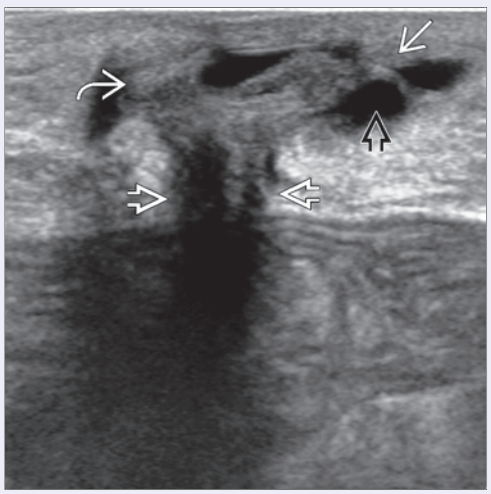
(Left) *Schematic diagram shows paraumbilical hernia arising from the umbilicus area. The location of epigastric, spigelian, and hypogastric herniae is also shown for reference.* ***(Right)*** *Clinical photograph shows a typical appearance of a small paraumbilical hernia in an adult with swelling at the superior aspect of the umbilicus.*





(Left) *Transverse ultrasound in the same patient as previous image shows a small paraumbilical hernia. The sac contains echogenic fat and no bowel. The margins of the defect in the linea alba are clearly seen.* ***(Right)*** *Transverse ultrasound in another patient shows a medium-sized paraumbilical hernia extending through a defect in the linea alba at the umbilicus. The sac contains both echogenic omental fat and hypoechoic peritoneal fluid. No bowel content is present.*





ABDOMINAL WALL HERNIA

TERMINOLOGY

Definitions

- Hernia: Abnormal protrusion of an organ or part of an organ out of the cavity in which it is normally contained
  - Reducible: Hernia that can disappear either spontaneously or with external pressure
  - Obstructed: Hernia leading to mechanical bowel obstruction
  - Strangulated: Hernia causing mechanical constriction of vascular supply to contents of hernia
  - Incarcerated: Hernia that cannot be reduced
- Classification: Ventral hernia, incisional hernia, fatty hernia of linea alba, epigastric hernia, umbilical hernia, hypogastric hernia, spigelian hernia, lumbar hernia

IMAGING

General Features

- Best diagnostic clue
  - Abdominal wall lump due to tissue protruding though defect in abdominal wall
- Location
  - Midline hernias
    - Epigastric: Between xiphisternum and umbilicus
    - Umbilical: Umbilical or immediate paraumbilical region
    - Hypogastric: Between umbilicus and pubic symphysis
  - Lateral hernias
    - Spigelian
      - Defect in transversus abdominis aponeurosis just lateral to rectus sheath (linea semilunaris)
      - Most commonly located near arcuate line
    - Lumbar: Occur in 2 potentially weak areas of flank
      - Superior lumbar triangle (Grynfeltt hernia) bounded by erector spinae medially, 12th rib superiorly, and internal oblique muscle laterally
      - Inferior lumbar triangle (Petit hernia) bounded by latissimus dorsi muscle medially, iliac crest inferiorly, and external oblique muscle laterally
  - Incisional hernia: Located at surgical incisional site
- Morphology
  - Abdominal wall; anatomy
    - Layers: Skin, subcutaneous fat, musculofascial layer, transversalis fascia, and extraperitoneal fat
    - Musculofascial layer
      - Anterior wall: Paired rectus muscles enclosed by rectus sheath (aponeurosis of internal oblique, external oblique, and transversus abdominis muscles), which laterally forms linea semilunaris and centrally fuses to form linea alba
      - Anterolateral-lateral wall: External oblique, internal oblique, and transversus abdominis
      - Posterior wall: Quadratus lumborum and erector spinae muscles
    - Arcuate line: Caudal aspect of posterior rectus sheath ends at arcuate line, midway between umbilicus & pubic symphysis
    - Distal to arcuate line, rectus muscle is separated from peritoneum only by transversalis fascia, as aponeuroses of internal oblique, external oblique, and transversus abdominis pass anterior to rectus muscle
  - Epigastric hernia
    - Usually small and contains extraperitoneal fat that protrudes through linea alba (fatty hernia of linea alba)
    - May occasionally be large and contains bowel
  - Umbilical hernia
    - Umbilical in children
      - Peritoneal content protrudes through patent umbilical ring
    - Paraumbilical in adults
      - Extraperitoneal fat ± peritoneal contents protrudes through 1 side of umbilical ring
  - Hypogastric hernia
    - Very uncommon
  - Spigelian hernia
    - Usually extend into subcutaneous layer though may pass between transversus abdominus and internal oblique muscles or may extend into rectus sheath
      - Can present as flank lump if extends laterally
    - Sometimes secondary to trauma
  - Lumbar hernia
    - Usually painless due to wide hernial neck
  - Incisional hernia
    - Occurs in 0.5-14% of postoperative patients
    - May occur years after surgery, though usually occurs within 1st year
    - May go unnoticed by patient and be incidentally detected on imaging
      - Can be very large

CT Findings

- Accurate at assessing presence of hernia and identifying sac contents as well as site and size of abdominal wall defect
  - Useful for assessing larger deep-seated hernias

Ultrasonographic Findings

- Grayscale ultrasound
  - Identifies nature of herniated content (omentum, bowel), site/size of abdominal wall defect and complications
    - Omental fat: Echogenic/hypoechoic tissue without peristalsis
    - Bowel: "Target" echo pattern with strong central echoes due to air in lumen and visible peristalsis
      - May see valvulae conniventes (small bowel) or feculent content (large bowel)
      - Variable appearances due to air-fluid content
  - Reducibility
    - Reduction in hernia size with ↓ in intraabdominal pressure or application of transducer pressure onto hernial sac
    - An irreducible hernia may proceed to become obstructed or strangulated
      - These complications are uncommon in noninguinal abdominal wall hernias
  - Obstruction
    - Nonobstructed hernia: Shows active peristalsis and movement of intestinal contents
    - Obstructed hernia: Is an irreducible hernia with narrow neck and features of bowel obstruction

ABDOMINAL WALL HERNIA

- Not easy to diagnose with ultrasound; better appreciated with radiography or CT
- Strangulation
  - No flow on color Doppler imaging within bowel wall or mesentery, swollen bowel wall, and aperistalsis
    - Not reliable sign as many nonstrangulated hernia do not show flow on color Doppler imaging
    - Other signs are also unreliable, making it difficult to assess strangulation on ultrasound

Imaging Recommendations

- Best imaging tool
  - Ultrasound is accurate and dynamic
    - CT or MR ± herniography if ultrasound is negative or equivocal
- Protocol advice
  - Identify anatomical layers, localize focal abdominal wall defect, compare with opposite side (if possible), and identify hernial contents
    - Use light transducer pressure to minimize nonappearance of hernia
    - Valsalva maneuver is used routinely
    - May or may not examine in standing position if this clinically accentuates hernia
    - Increase in hernial sac size with Valsalva maneuver or standing upright
    - Measure size of hernial sac as well as size of fascial defect
    - If bowel content, check for complications (irreducibility/obstruction/strangulation)

DIFFERENTIAL DIAGNOSIS

Abdominal Wall Tumor

- Primary (lipoma, desmoid tumor, endometriosis) or secondary tumor (scar metastasis, melanoma metastases, Sister Mary Joseph nodule)

Abdominal Wall Abscess or Seroma

- No fascial defect present

Abdominal Wall or Rectus Sheath Hematoma

- Post-traumatic or spontaneous: Bleeding of epigastric vessels or muscle tear
- No fascial defect present

Divarication of Rectus Abdominis Muscles

- Bulging of abdominal cavity due to stretching and thinning of linea alba
  - Particularly in elderly multiparous women

PATHOLOGY

General Features

- Etiology
  - Chronic increased intraabdominal pressure, abdominal distension (ascites) ± muscle laxity (obesity, old age)
    - Weak abdominal wall musculature
    - Physical exertion, chronic cough, prostatism, or constipation
  - Trauma: Blunt force or hyperextension strain
    - Insufficient to penetrate skin but strong enough to disrupt muscle and fascia
    - Sudden ↑ in intraabdominal pressure
  - Postoperative abdominal wall weakness, surgical scar, suture dehiscence
  - Epigastric hernia may be related to anomalous slips from diaphragm to linea alba region
  - Umbilical hernia related to periumbilical fascial defect

CLINICAL ISSUES

Presentation

- Most common signs/symptoms
  - Abdominal lump increasing in size with ↑ in intraabdominal pressure
  - Reducible swelling with a positive cough impulse
  - Intermittent intestinal obstruction

Demographics

- Age
  - Umbilical hernia: Young children; paraumbilical hernia: Adults
  - Epigastric hernia: 20- 50 years
  - Incisional hernia: More frequent in elderly
- Gender
  - Epigastric hernia is 2x more common in males
- Epidemiology
  - Most common abdominal wall lesion seen in ultrasound practice

Natural History & Prognosis

- ~ 1/3 of umbilical hernias close within 1 month of birth and rarely persist beyond 3–4 years
- All other hernias persist and frequently enlarge with time

Treatment

- Repair of muscle/fascial defect: Open or laparoscopic technique, meshplasty
- Intestinal obstruction/strangulated hernia; urgent exploratory laparotomy

DIAGNOSTIC CHECKLIST

Consider

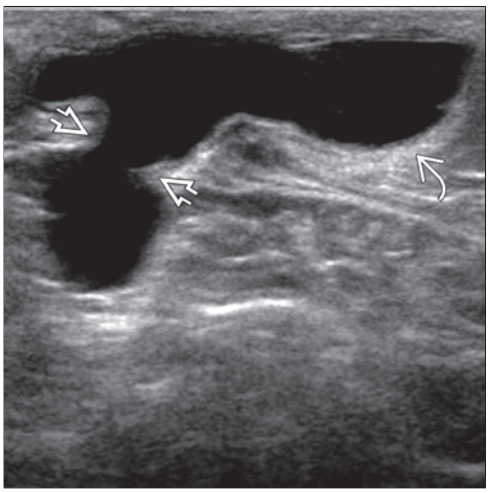
- Abdominal wall hernia if posterior margin of any abdominal wall mass cannot be seen on ultrasound

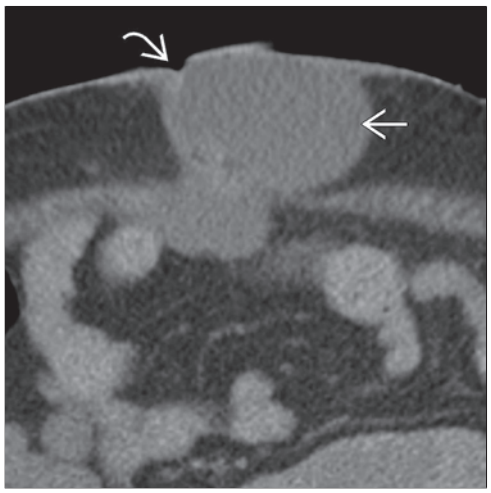
Image Interpretation Pearls

- Check for abdominal wall defect, hernial sac contents, peristaltic movement, and vascularity (if bowel)

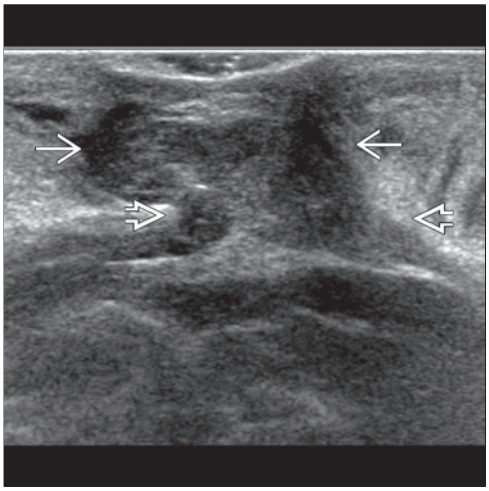
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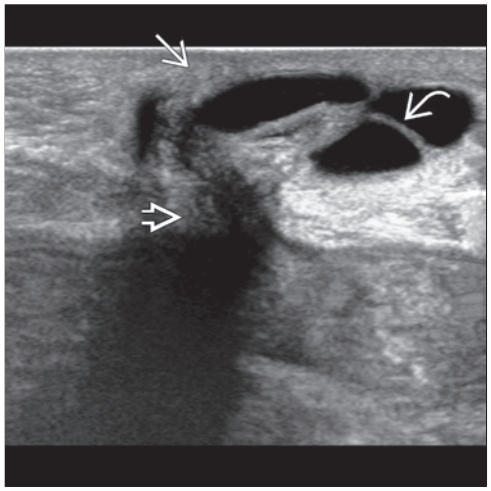
1. Arend CF: Static and dynamic sonography for diagnosis of abdominal wall hernias. J Ultrasound Med. 32(7):1251-9, 2013
2. Lee RK et al: Ultrasound of the abdominal wall and groin. Can Assoc Radiol J. 64(4):295-305, 2013



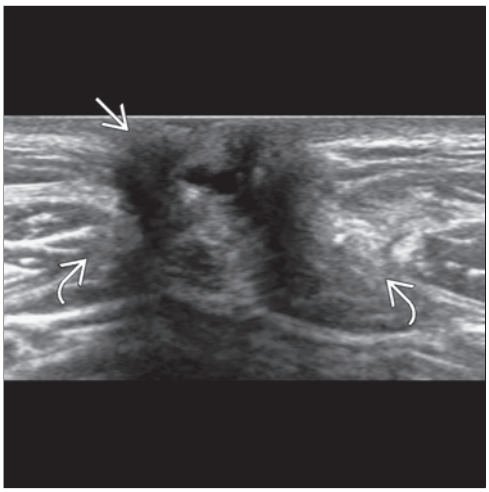


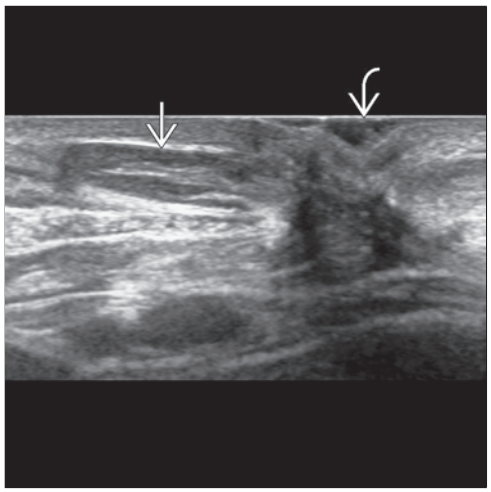
(Left) *Transverse ultrasound shows a large umbilical hernia protruding through a defect in the linea alba at the umbilicus. The sac contains peritoneal fluid. This seemed to be encysted as it was not readily reducible. No bowel content is present.* ***(Right)*** *Axial NECT of the same patient shows a large paraumbilical hernia. The sac content is made up entirely of encysted peritoneal fluid. No bowel content is present. The hernia bulges to the side of the umbilicus.*





(Left) *Transverse ultrasound shows a medium-sized umbilical hernia. The hernial sac is filled with omental fat. No bowel content is present. The defect in the linea alba at the umbilicus is wide.* ***(Right)*** *Transverse ultrasound shows a medium-sized umbilical hernia. The hernial sac contains strands of omentum as well as encysted peritoneal fluid. No bowel content is present. The hernial neck often shows acoustic shadowing despite the absence of bowel content due to the compactness of tissues in this area.*

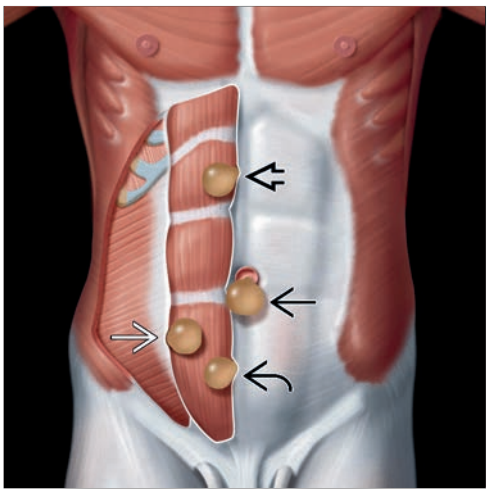


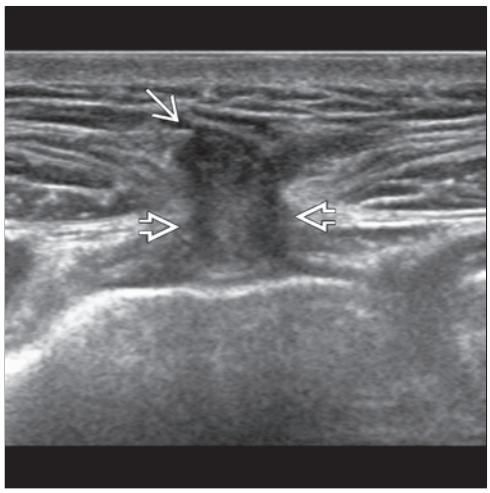


(Left) *Transverse ultrasound shows a small umbilical hernia extending though a wide defect in the linea alba.* ***(Right)*** *Longitudinal ultrasound of same patient shows that the umbilical hernia contains bowel and extends cephalad from the umbilicus within subcutaneous fat. Umbilical hernias in adults are more common in overweight subjects and following pregnancy.*

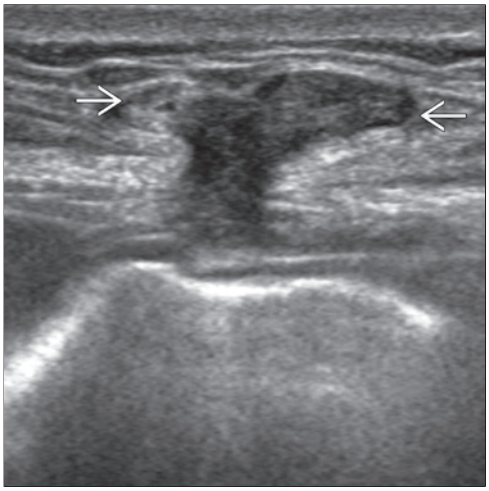
ABDOMINAL WALL HERNIA

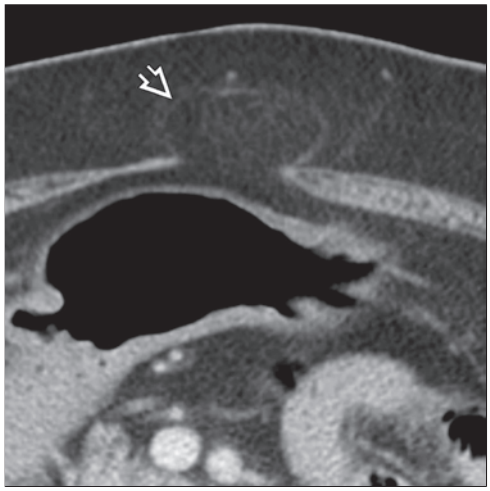
(Left) *Schematic diagram shows an epigastric and hypogastric linea alba hernias arising from the midline. The location of umbilical and spigelian herniae is also shown for reference.* ***(Right)*** *Transverse ultrasound shows a small epigastric hernia in the supraumbilical region (also called linea alba hernia). This contains hypoechoic extraperitoneal fat. The defect in the linea alba is clearly seen. Fat may appear as either hypoechoic or hyperechoic on ultrasound.*



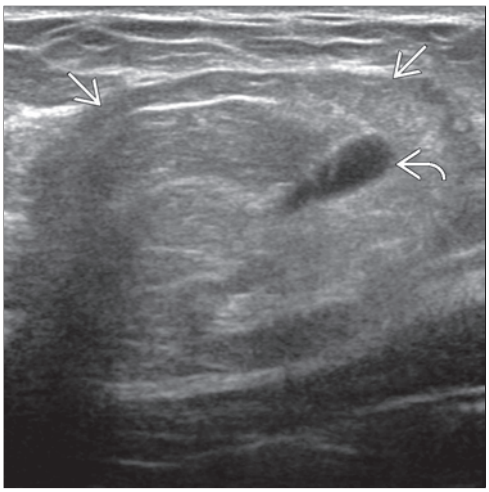


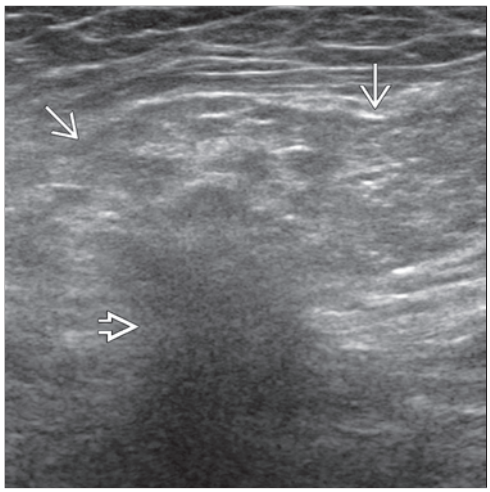
(Left) *Transverse ultrasound shows a small epigastric hernia containing hypoechoic extraperitoneal fat.* ***(Right)*** *Axial CECT of the same patient obtained several weeks after ultrasound examination shows how the wall of the epigastric hernia is very thin. The hernial sac is larger than on ultrasound. This may be due to interim increase in hernial sac size or due to the effect of transducer pressure on sac size.*

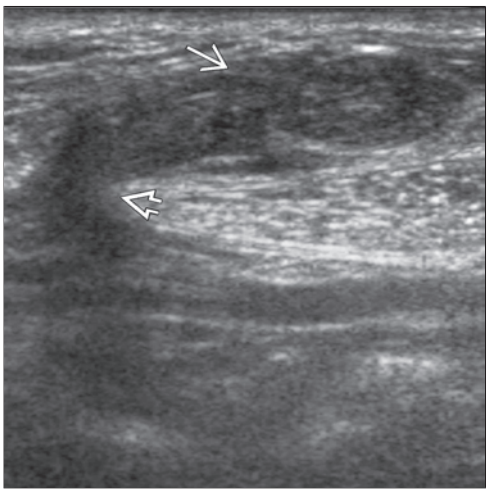


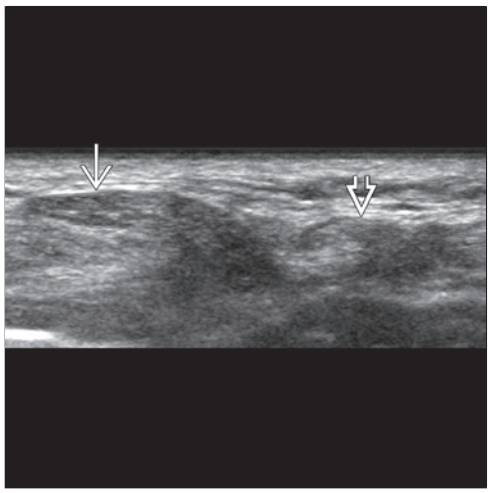


(Left) *Transverse ultrasound shows an unusually large epigastric hernia containing hyperechoic mesenteric fat and a small amount of peritoneal fluid. No bowel is present.* ***(Right)*** *Transverse ultrasound shows another unusually large epigastric hernia containing mesenteric fat. There is acoustic shadowing present at the hernial neck. This is a common feature of hernia and does not imply bowel content in the hernial sac.*

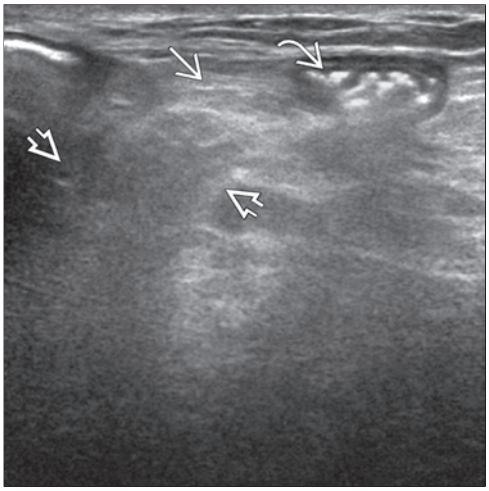


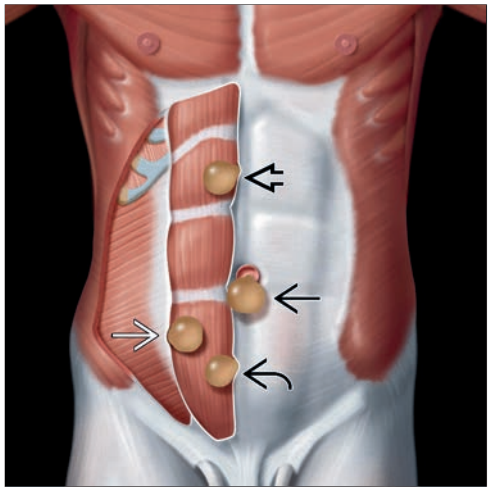




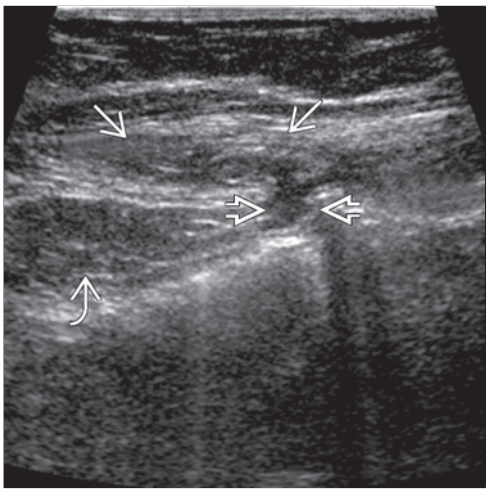


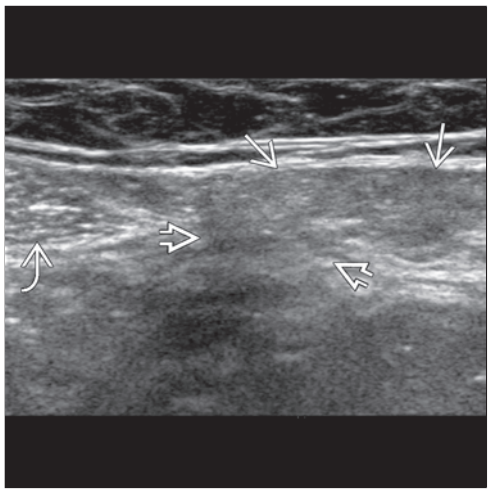
(Left) *Oblique ultrasound shows a medium-sized epigastric hernia extending through a small defect in the supraumbilical linea alba. The hernia contains hypoechoic extraperitoneal fat and extends caudally within the subcutaneous tissues.* ***(Right)*** *Longitudinal ultrasound shows 2 separate epigastric hernias. The superior hernia is larger in size than the inferior hernia and both contain fat. It is uncommon for 2 epigastric hernias to occur in the same patient.*





(Left) *Longitudinal ultrasound shows a large hypogastric hernia at the infraumbilical region. The sac contains both bowel and mesenteric fat.* ***(Right)*** *Schematic diagram shows a spigelian hernia extending through the linea semilunaris. The location of epigastric, umbilical, and hypogastric herniae is also shown for reference.*

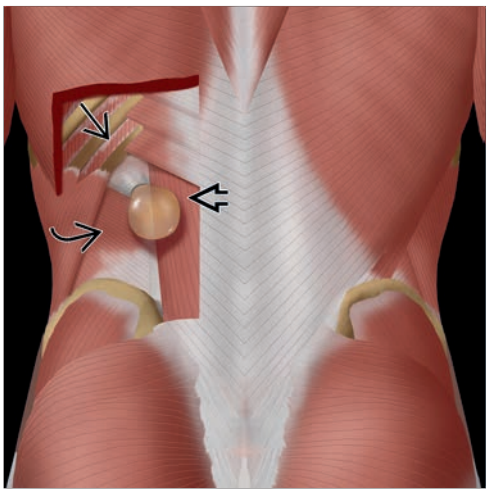


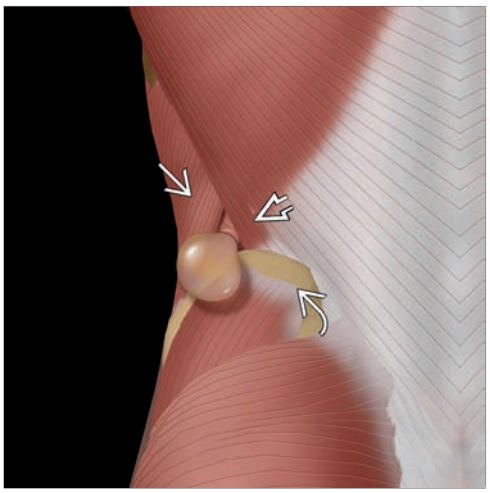


(Left) *Transverse ultrasound shows a medium-sized left spigelian hernia extending through a small defect in the transversus abdominis aponeurosis. The rectus abdominis muscle alongside the defect is normal.* ***(Right)*** *Transverse ultrasound shows another medium-sized spigelian hernia through a medium-sized defect in the transversus abdominis aponeurosis. The sac contains mesenteric fat though no bowel. The rectus abdominus muscle is shown.*

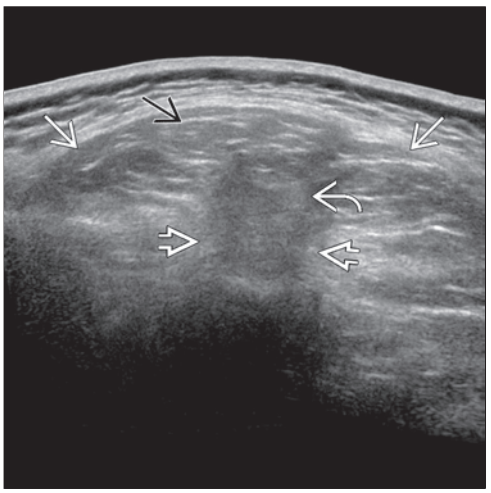
ABDOMINAL WALL HERNIA

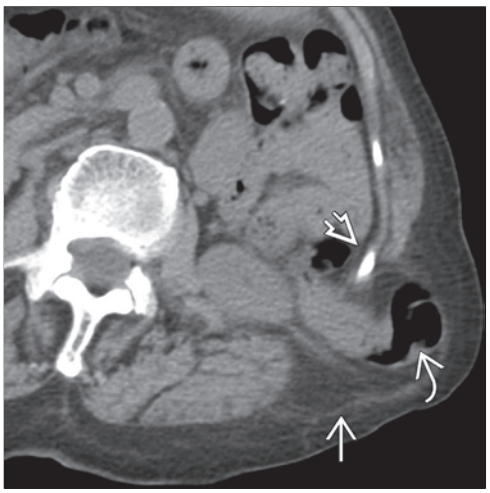
(Left) *Schematic diagram shows a superior lumbar hernia (Grynfeltt hernia) arising from the superior lumbar triangle bounded by the erector spinae muscle medially, the 12th rib superiorly, and the internal oblique muscle laterally.* ***(Right)*** *Schematic diagram shows an inferior lumbar hernia (Petit hernia) arising from the inferior lumbar triangle bounded by the latissimus dorsi muscle medially, the iliac crest inferiorly, and the external oblique muscle laterally.*



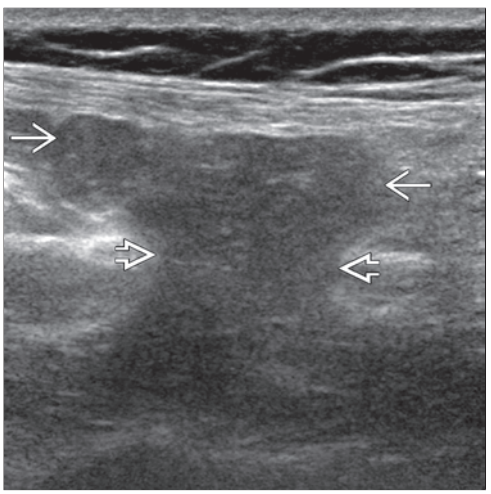


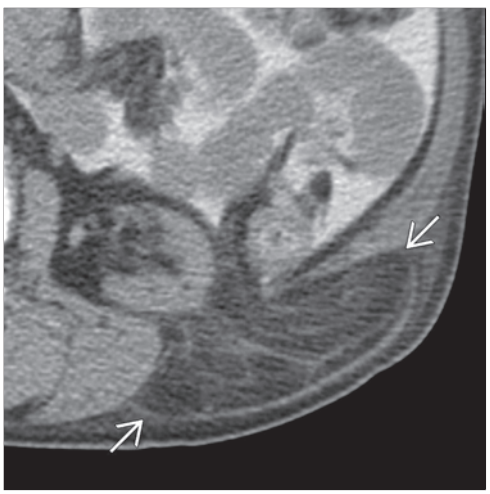
(Left) *Transverse ultrasound shows a large lumbar hernia extending through a defect in the superior lumbar triangle. The sac contains both bowel and mesenteric fat.* ***(Right)*** *Axial NECT of the same patient shows the large lumbar hernia extending through the superior lumbar triangle and containing bowel and intraperitoneal fat. The 12th rib is shown. Lumbar hernia may contain intra- or extraperitoneal content and, therefore, benefit from CT examination.*

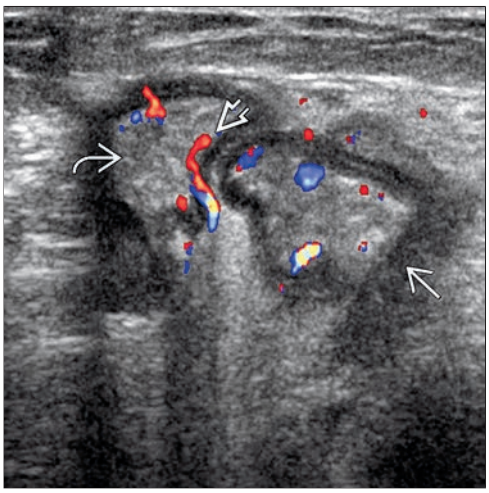


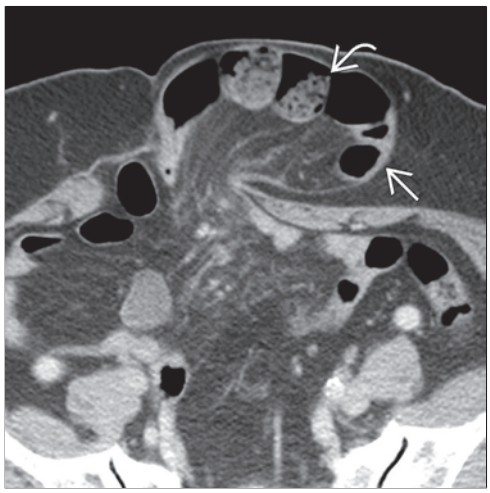


(Left) *Oblique ultrasound shows a large lumbar hernia extending through a wide defect in the superior lumbar triangle. The hernia contains hypoechoic fat though it is not clear on ultrasound whether this fat is intraperitoneal or extraperitoneal in origin.* ***(Right)*** *Axial NECT of the same patient shows the large lumbar hernia containing retroperitoneal fat. The colon, spleen, liver, and kidney may all herniate through either superior or inferior lumbar triangle defects.*

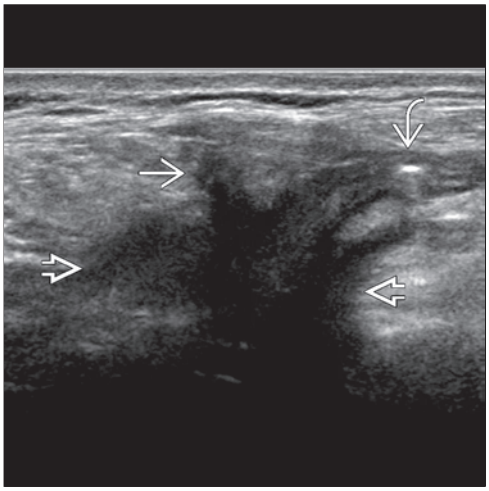


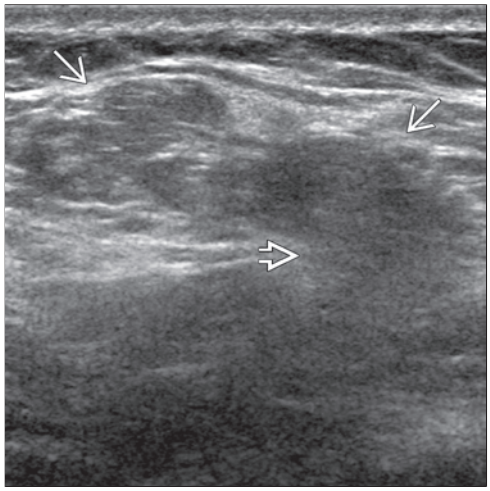




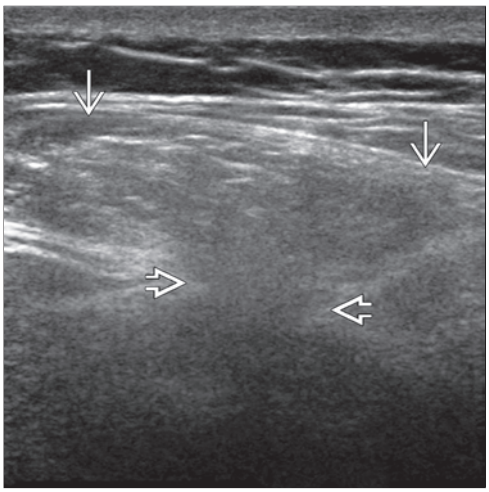


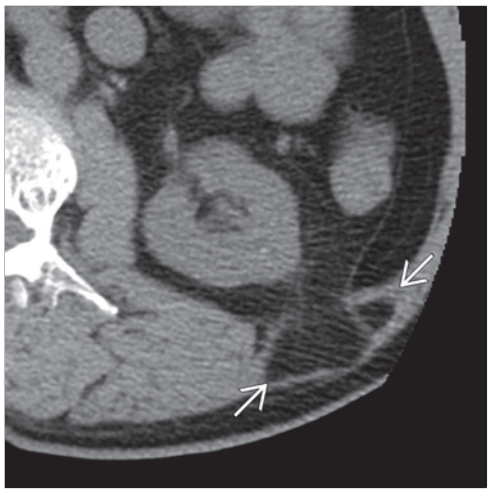
(Left) *Transverse color Doppler ultrasound shows a large incisional hernia ➔ extending through a midline abdominal incision. The sac contains mainly bowel ➔. This bowel is well vascularized ➔ though the absence of vascularity on color Doppler imaging does not necessarily imply ischemia.* ***(Right)*** *Axial NECT of the same patient shows the large incisional hernia ➔ extending through a defect in the anterior abdominal wall. The bowel ➔ within the hernia sac is normal in appearance.*





(Left) *Transverse ultrasound shows a medium-sized incisional hernia ➔ extending through a defect ➔ at the parastomal site. The sac contains a small amount of gas ➔, which is indicative of some bowel content.* ***(Right)*** *Transverse ultrasound shows a large incisional hernia ➔ extending through a previous surgical incision ➔ in the anterior abdominal wall. Incisional hernias are often large at presentation and tend to enlarge even further with time.*





(Left) *Transverse ultrasound shows a large incisional hernia ➔ at the site of prior percutaneous nephrostomy ➔. The sac contains the retroperitoneal fat.* ***(Right)*** *Axial NECT of the same patient shows the large incisional hernia ➔. The sac contains retroperitoneal fat. The site of the hernia is similar to the site of superior lumbar hernia; however, in this situation the hernia followed a percutaneous procedure at this site and is therefore deemed an incisional hernia.*

GROIN HERNIA

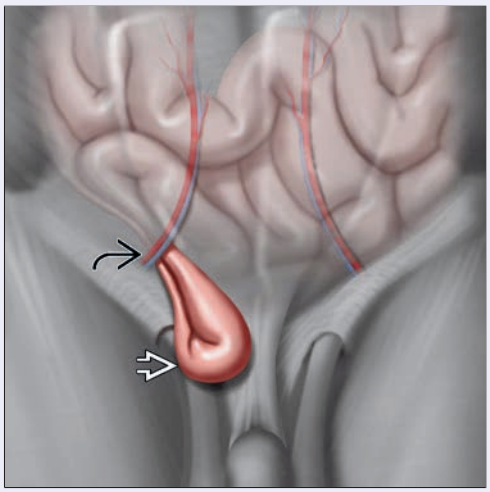
Key Facts

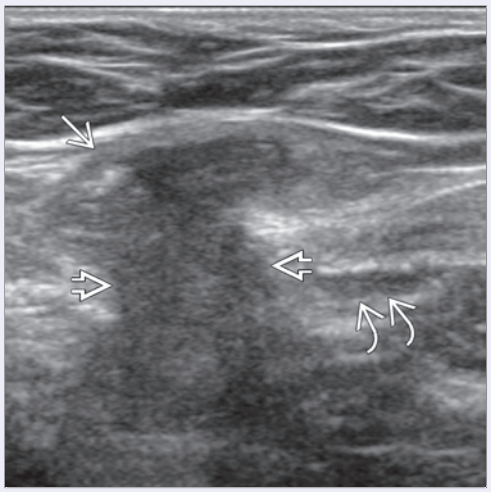
Terminology
- Indirect inguinal hernia, direct inguinal hernia, femoral hernia
- Hernia: Abnormal protrusion of an organ or part of organ out of cavity in which it is normally contained

Imaging
- **Indirect inguinal hernia**: Passes through deep inguinal ring, extends along inguinal canal, and emerges at superficial inguinal ring
- **Direct inguinal hernia**: Passes through transversalis fascia in Hesselbach triangle
- **Femoral hernia**: Passes through femoral canal
- Identify inguinal ligament, inferior epigastric artery, and spermatic cord
- Trace spermatic cord in transverse plane retrogradely from high scrotal area to deep inguinal ring
- Specifically examine deep inguinal ring, Hesselbach triangle, and femoral canal areas
- Examine each area at rest and during Valsalva
- Determine presence of hernia ± laxity of fascia
- ± reexamine with patient standing erect
- Ultrasound: 97% sensitivity, 86% specificity, and 93% positive predictive value for diagnosis of groin hernia
  - Pure fatty hernia is most difficult to diagnose
  - Lower accuracy for determining specific hernia type
- CT or MR: Useful if ultrasound is equivocal

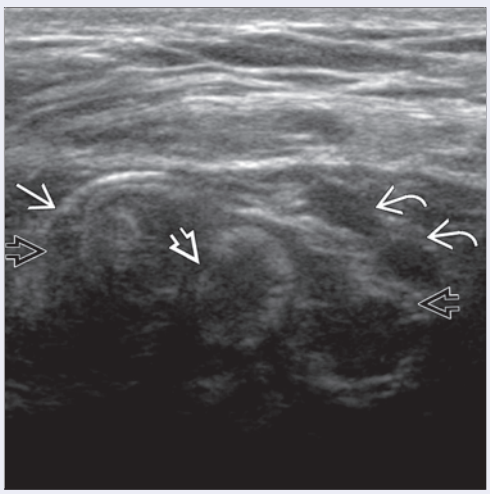
Diagnostic Checklist
- Indirect inguinal hernia neck: Above inguinal ligament & lateral to inferior epigastric artery
- Direct inguinal hernia neck: Above inguinal ligament & medial to inferior epigastric artery
- Femoral hernia: Below inguinal ligament

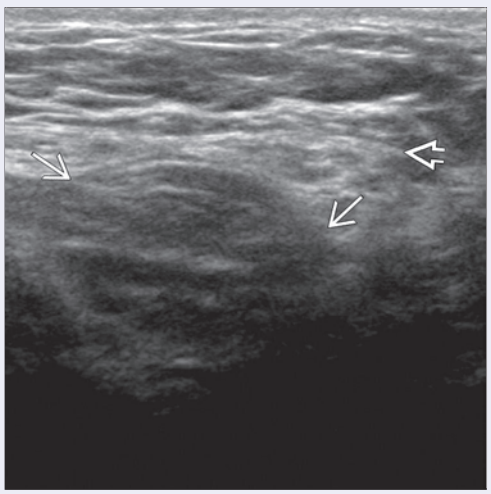
(Left) *Graphic shows a direct inguinal hernia. Note that the neck of a direct inguinal hernia is medial to the inferior epigastric vessels. A direct inguinal hernia passes through transversalis fascial defect in Hesselbach triangle.* ***(Right)*** *Transverse ultrasound shows a left direct-type inguinal hernia containing hypoechoic mesenteric fat. The neck of the hernia lies medial to the inferior epigastric vessels.*





(Left) *Transverse ultrasound shows a left direct-type inguinal hernia containing bowel. The neck of the hernia is wide and lies medial to the inferior epigastric vessels. Obstruction is rare in direct inguinal herniae as they usually have a wide neck.* ***(Right)*** *Longitudinal ultrasound of the same hernia shows that it is a direct-type inguinal hernia that arises cephalad to the inguinal ligament. The inguinal ligament is difficult to appreciate on still images but is more readily appreciable in real time.*





GROIN HERNIA

TERMINOLOGY

Synonyms
- Inguinal hernia, indirect inguinal hernia, direct inguinal hernia, femoral hernia

Definitions
- Abnormal protrusion of organ or part of organ out of cavity in which it is normally contained

IMAGING

General Features
- Location
  - **Inguinal canal**
    - ~ 4 cm long, ~ 1.2 cm above inguinal ligament
      - Contains spermatic cord and ilioinguinal nerve in males, round ligament of uterus and ilioinguinal nerve in females
    - Has floor, anterior wall, roof, and posterior wall
    - Floor: Inguinal ligament formed from thickened free lowermost border of external oblique aponeurosis
      - Runs from anterior superior iliac spine to pubic tubercle
    - Anterior wall: External oblique fascia
      - Triangular defect medially forms superficial inguinal ring
    - Roof: Internal oblique and transversus abdominus fascia
      - Attached to lateral part of inguinal ligament
      - Medially arch over superficial inguinal ring as conjoint tendon
    - Posterior wall: Transversalis fascia
      - Contains rounded defect midway between anterior superior iliac spine and pubic tubercle, known as deep inguinal ring
    - Inferior epigastric artery from external iliac artery runs just medial to deep inguinal ring on way to rectus sheath
    - Hesselbach triangle located between inferior epigastric artery laterally, rectus sheath medially, and inguinal ligament inferiorly
  - **Femoral canal**
    - ~ 2 cm long, just medial to femoral vein, deep and distal to inguinal ligament
    - Anterosuperior border: Inguinal ligament
    - Medial border: Lacunar ligament (reflection of inguinal ligament to pectineal line)
    - Inferior border: Pectineal ligament (reflection of inguinal ligament over superior pubic ramus)
    - Lateral border: Femoral vein
  - **Indirect inguinal hernia**
    - Passes through deep inguinal ring, extends along inguinal canal, and emerges at superficial inguinal ring
    - Neck is lateral to inferior epigastric artery and above inguinal ligament
    - In males, usually extends along spermatic cord to scrotum
    - In females, may extend along round ligament to labia majora
  - **Direct inguinal hernia**
    - Passes through transversalis fascial defect in Hesselbach triangle
    - Wide neck medial to inferior epigastric artery and above inguinal ligament
    - Does not pass into spermatic cord and generally does not extend to scrotum
  - **Femoral hernia**
    - Passes through femoral canal
    - Narrow neck medial to femoral vein and below inguinal ligament
  - **Double hernia**
    - Simultaneous occurrence of direct and indirect inguinal hernia in same groin
    - a.k.a. saddlebag hernia

Radiographic Findings
- Radiography
  - Convergence of distended intestinal loops toward inguinal region
  - ± small or large bowel obstruction
  - Herniography: Injection of soluble low osmolar contrast medium into peritoneal cavity

Ultrasonographic Findings
- Grayscale ultrasound
  - Accurate at identifying presence and site of hernia as well as contents of hernial sac (bowel or omentum)
    - Omental fat: Echogenic tissue without peristalsis
    - Bowel: Intestinal loops; "target" echo pattern with strong central echoes representing air or fluid in lumen ± peristalsis
      - Nonobstructed hernia: Active peristalsis ± movement of intestinal contents
      - Obstructed hernia: No movement of intestinal content in hernia and dilated bowel loops in abdomen, may have peristalsis
  - Reducible hernia
    - Decrease in hernia size with decrease in intraabdominal pressure or application of external pressure to hernial sac with transducer
    - Increase in hernia size during cough, Valsalva maneuver, or standing
- Color Doppler
  - Helps identify inferior epigastric artery and its relationship to hernia sac
    - Helps discriminate between direct and indirect inguinal herniae
  - Strangulated hernia; absence of vascularity within bowel wall and mesentery
    - Not a very reliable sign

Imaging Recommendations
- Best imaging tool
  - Ultrasound is accurate provided that strict systematic approach is used
    - 97% sensitivity, 86% specificity, and 93% positive predictive value for diagnosis of groin hernia
    - Pure fatty hernia is most difficult to diagnose on ultrasound
    - Lower accuracy for determining type of hernia (indirect inguinal, direct inguinal, femoral)
  - CT or MR is useful if ultrasound is equivocal
    - Use low-dose CT technique if specifically looking for herniae
- Protocol advice

GROIN HERNIA

- 1st identify inferior epigastric artery, spermatic cord (or round ligament), and inguinal ligament
  - Inferior epigastric vessels identified at lateral margin of rectus femoris muscle and traced distally
- Trace spermatic cord in transverse plane retrogradely from high scrotal area to deep inguinal ring
- Specifically examine deep inguinal ring, Hesselbach triangle area, and femoral canal
- At each area, examine at rest and ask patient to perform Valsalva maneuver
  - Look for presence of hernia or laxity (bulging) of fascia (on Valsalva maneuver)
  - Ideally, obtain video clip
  - Can reexamine specific areas with patient standing if this clinically accentuates symptoms
- Identification of a hernia at 1 location does not preclude occurrence of hernia at another location so all 3 areas should be routinely examined

DIFFERENTIAL DIAGNOSIS

Lipoma of Spermatic Cord

- No change with Valsalva maneuver, not reducible
- Usually no deep extension into peritoneal cavity

Encysted Hydrocele Canal of Nück

- Embryologically, processus vaginalis extends from peritoneal cavity to scrotum
  - Normally obliterates in cord while scrotal component persists as tunica vaginalis
  - Failure of obliteration leads to fluid distension within cord, known as encysted hydrocele canal of Nück
    - Filled with anechoic fluid, no change with Valsalva maneuver, not reducible
    - No deep extension into peritoneal cavity

PATHOLOGY

General Features

- Etiology
  - Chronic increased intraabdominal pressure, abdominal distension (ascites) ± muscle laxity
    - Weak abdominal musculature, chronic cough, prostatism, constipation, manual labor
  - Indirect inguinal hernia: Congenital due to persistence of processus vaginalis
  - Direct inguinal hernia; Acquired due to transversalis fascia weakness in Hesselbach triangle
  - Femoral hernia: Weakness of femoral canal

Gross Pathologic & Surgical Features

- Sac contents: Commonly omentum, small bowel, or mobile colon segments (sigmoid, cecum, appendix)
  - Sliding hernia: Sac contains retroperitoneal organs
    - Urinary bladder, distal ureters, or ascending/descending colon
  - Littre hernia: Meckel diverticulum in sac
  - Richter hernia: Only portion of bowel circumference (antimesenteric portion) in sac

CLINICAL ISSUES

Presentation

- Most common signs/symptoms
  - Groin lump or discomfort
    - Continuous or intermittent
- Other signs/symptoms
  - Features of intestinal obstruction

Demographics

- Age
  - Indirect inguinal hernia tend to occur in young to middle-aged individuals
  - Prevalence of direct inguinal hernia increases with increasing age
  - Femoral hernia is more common in middle-aged to elderly individuals
- Gender
  - Indirect inguinal hernia is 5-10x more common in males
  - Direct inguinal hernia nearly always occurs in males
  - Femoral hernia is more common in females
    - However, indirect inguinal hernia is most common hernia in females
- Epidemiology
  - 5% of males develop groin hernia
  - 75% of all hernias occur in inguinal region
  - Indirect inguinal herniae are 5x more common than direct inguinal herniae
    - Femoral hernia is much less common
  - Inguinal hernia in children is always the result of patent processus vaginalis and is thus an indirect hernia extending to scrotal sac
    - Affects 2% of all children
    - Most often seen in premature infants, particularly on right side (75%), bilateral (10%)

Natural History & Prognosis

- Herniae recur after herniorrhaphy in 20% of patients
  - Direct inguinal hernia may develop after repair of indirect inguinal hernia
- Complications: Obstruction, strangulation
  - Indirect inguinal herniae account for 15% of intestinal obstruction cases
  - Obstruction or strangulation is rare with direct inguinal herniae due to wide neck
  - Obstruction or strangulation is more common with femoral herniae due to narrow neck

Treatment

- Laparoscopic or open hernia repair

DIAGNOSTIC CHECKLIST

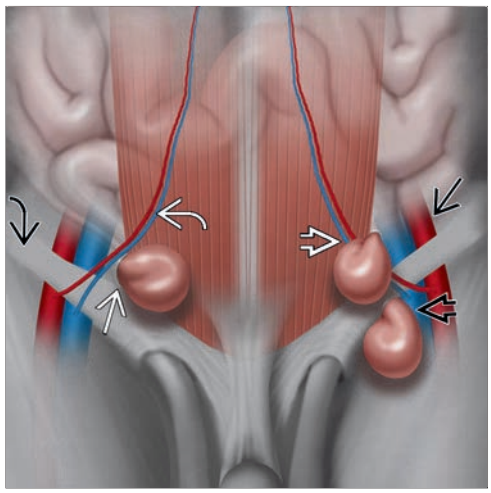
Consider

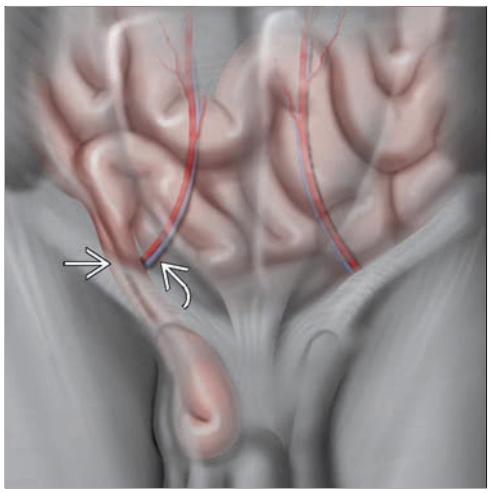
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- Femoral hernia: Below inguinal ligament

SELECTED REFERENCES

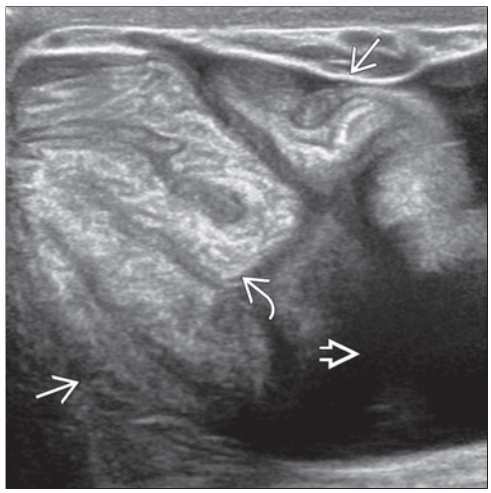
1. Lee RK et al: Ultrasound of the abdominal wall and groin. Can Assoc Radiol J. 64(4):295-305, 2013
2. Robinson A et al: Meta-analysis of sonography in the diagnosis of inguinal hernias. J Ultrasound Med. 32(2):339-46, 2013

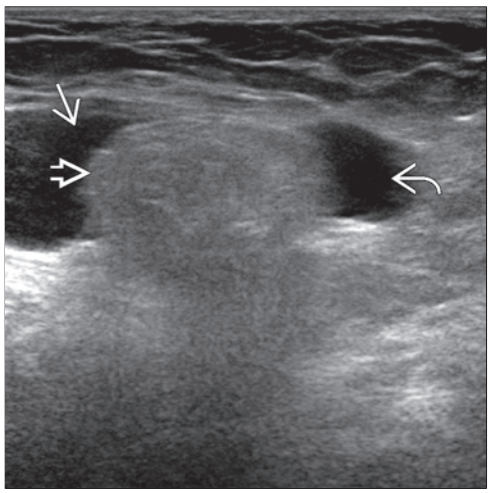
GROIN HERNIA



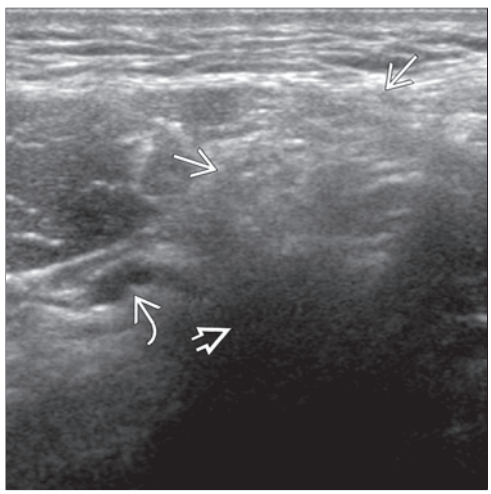


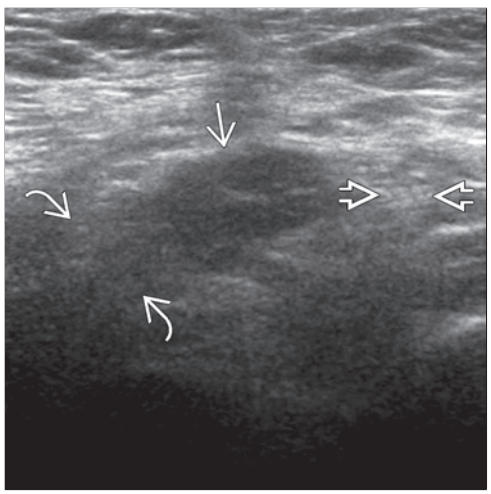
(Left) *Graphic shows 3 types of groin hernia. Direct and indirect inguinal herniae arise above the inguinal ligament and medial and lateral to the inferior epigastric vessels, respectively. Femoral hernias arise below the inguinal ligament and medial to the femoral vessels.* ***(Right)*** *Graphic shows an indirect inguinal hernia entering the right scrotal sac. Note that the neck of an indirect inguinal hernia lies lateral to the inferior epigastric vessels.*





(Left) *Transverse ultrasound shows a large indirect-type inguinal hernia extending into the upper scrotal region. There is fluid and bowel within the hernia sac.* ***(Right)*** *Transverse ultrasound shows a small indirect-type inguinal hernia. The sac contains fluid and mesenteric fat.*

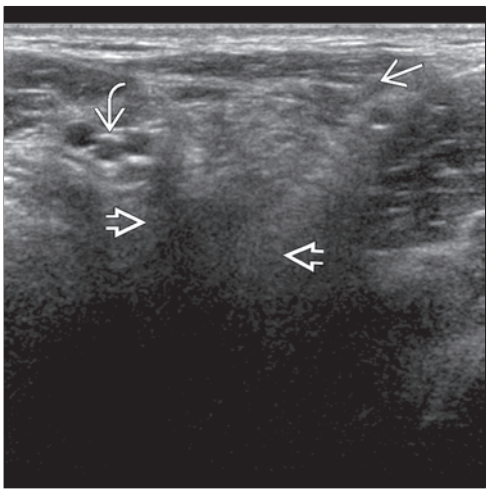


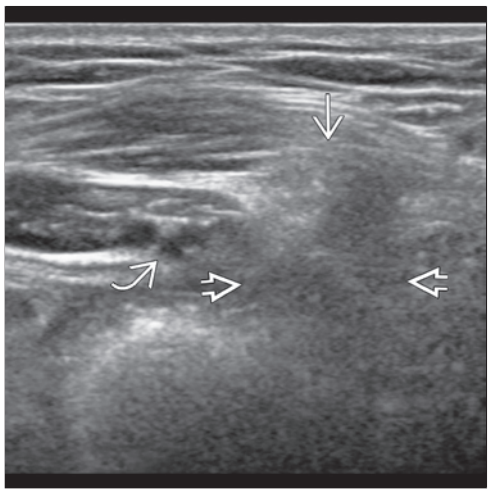


(Left) *Transverse ultrasound shows a left indirect-type inguinal hernia containing mesenteric fat and no bowel. The neck of the hernia lies lateral to the inferior epigastric vessels. Place the transducer over the deep inguinal ring before Valsalva maneuver. To-and-fro movement of the hernial sac can usually be observed on real-time imaging.* ***(Right)*** *Longitudinal ultrasound of the same hernia shows that the hernia neck lies cephalad to the inguinal ligament.*

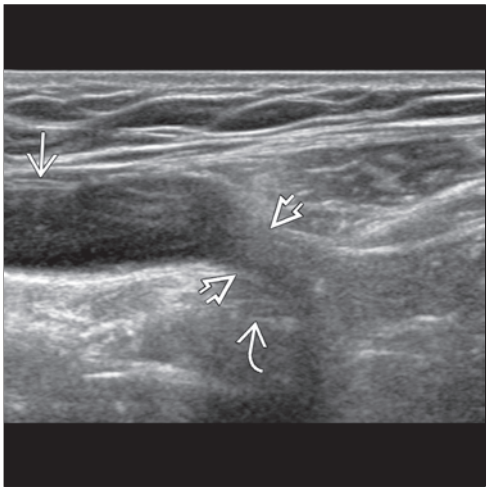
GROIN HERNIA

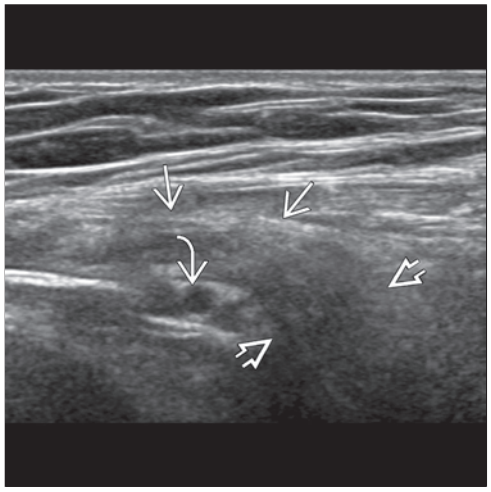
(Left) *Transverse ultrasound shows a left indirect-type inguinal hernia* ➔ *containing mesenteric fat. The neck* ➔ *of the hernia lies lateral to the epigastric veins and artery* ➔. ***(Right)*** *Transverse ultrasound shows a left indirect-type inguinal hernia* ➔ *containing mesenteric fat. The wide neck* ➔ *of the hernia lies lateral to the epigastric veins and artery* ➔. *Routine identification of pertinent anatomical structures helps determine the type of hernia present.*



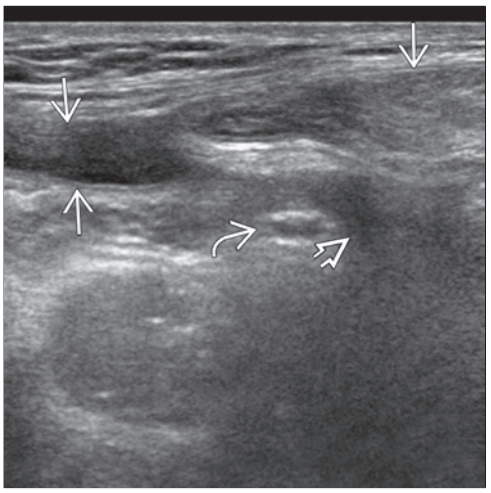


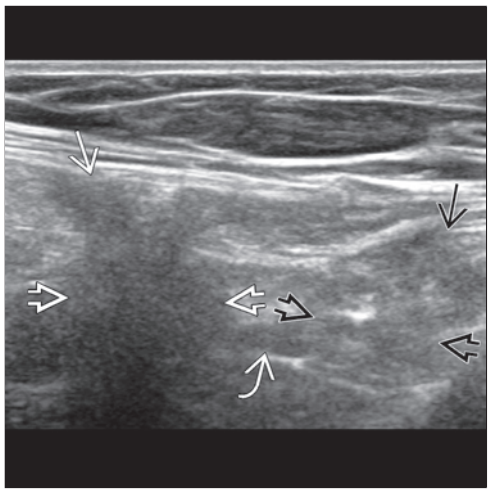
(Left) *Transverse ultrasound shows a left indirect-type inguinal hernia* ➔ *containing peritoneal fluid. The narrow hernia neck* ➔ *lies lateral to the epigastric vessels* ➔, *which are not clearly seen.* ***(Right)*** *Transverse ultrasound shows a left indirect-type inguinal hernia* ➔ *containing mesenteric fat. The hernia neck* ➔ *lies lateral to the epigastric veins and artery* ➔. *Indirect inguinal herniae are due to a persistence of the processus vaginalis.*

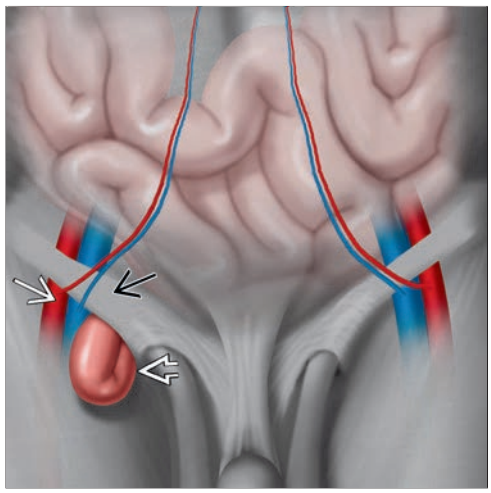


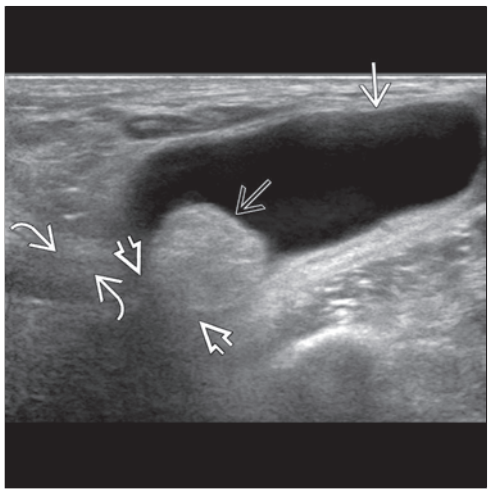


(Left) *Transverse ultrasound shows a left indirect-type inguinal hernia* ➔ *containing both fluid and mesenteric fat. The neck* ➔ *of the hernia lies lateral to the epigastric vessels* ➔. ***(Right)*** *Transverse ultrasound shows concurrent left direct* ➔ *and indirect* ➔ *inguinal herniae, both containing mesenteric fat. The necks of the indirect* ➔ *and direct* ➔ *herniae lie lateral and medial to the epigastric vessels* ➔, *respectively. This is known as a saddlebag hernia.*

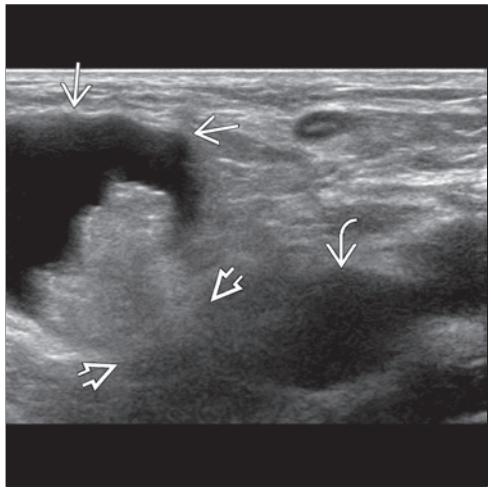


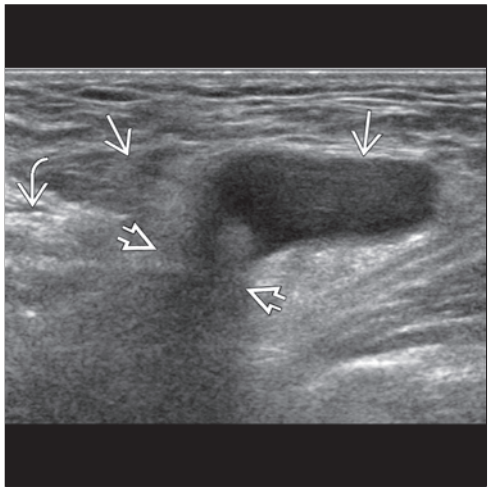




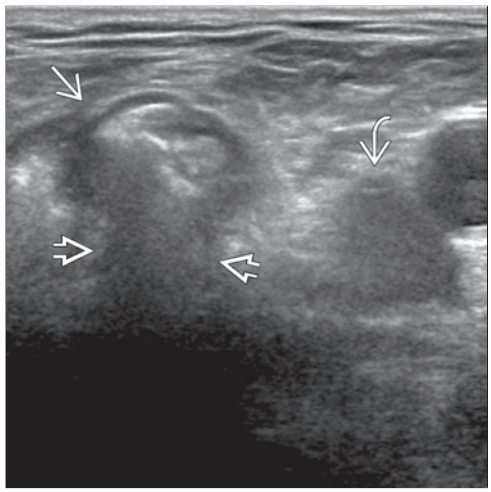


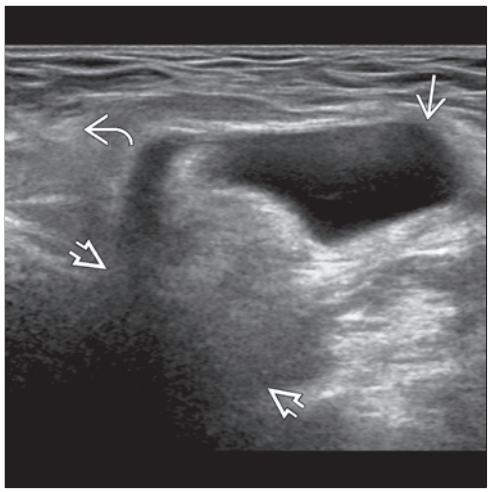
(Left) *Graphic shows a femoral hernia. Note that the neck of a femoral hernia is medial to the femoral vein and inferior to the inguinal ligament. **(Right)** Longitudinal ultrasound of a femoral hernia containing fluid and mesenteric fat shows that the neck of the hernia lies distal to the inguinal ligament. The relationship to the inguinal ligament helps mainly to discriminate between direct inguinal and femoral herniae, which are otherwise quite similar.*



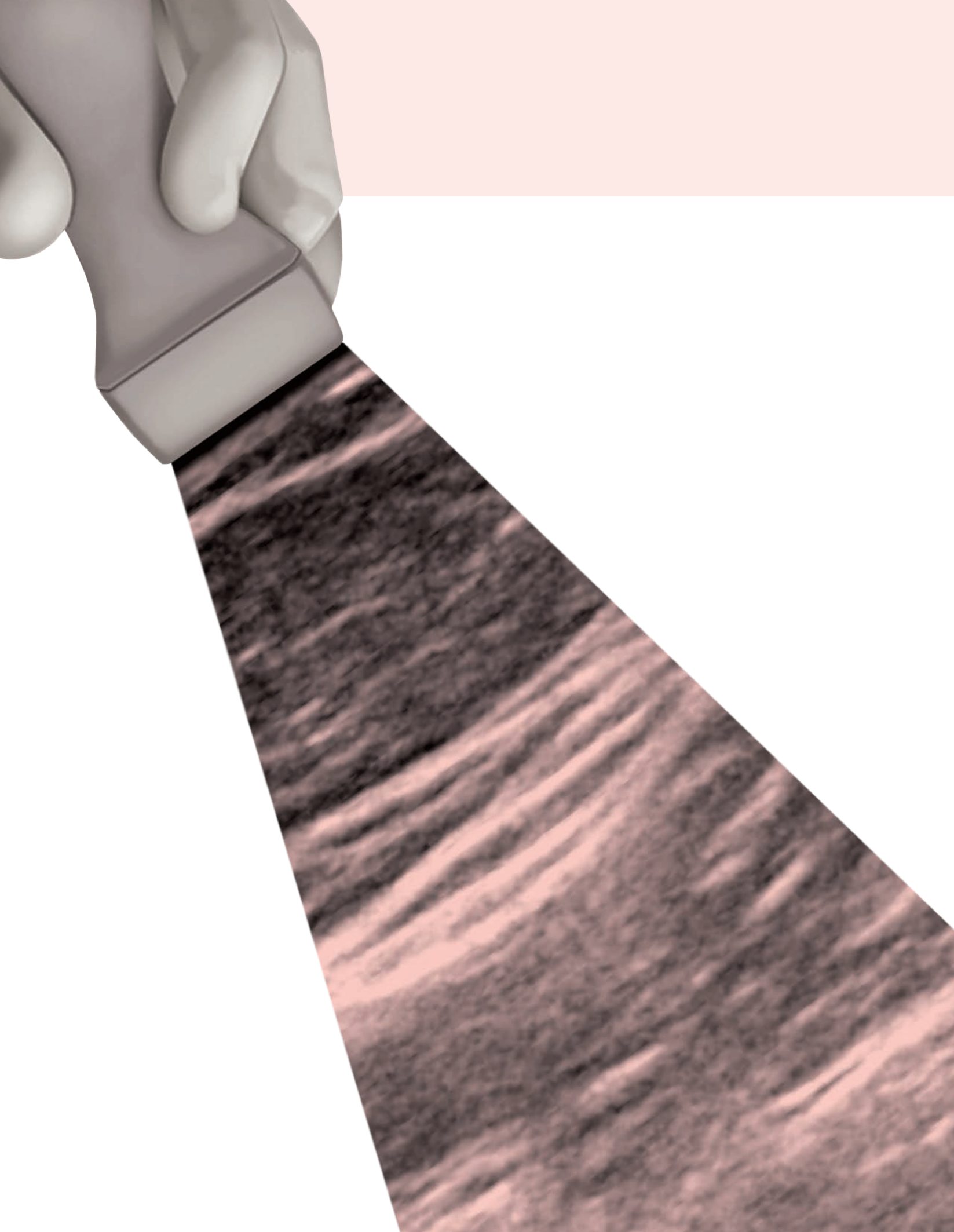


(Left) *Transverse ultrasound shows a left femoral hernia containing mesenteric fat and fluid. The neck of the hernia lies medial to the femoral vein and artery. **(Right)** Longitudinal ultrasound of the same femoral hernia shows that the neck of the hernia lies distal to the inguinal ligament. The narrow neck of femoral herniae makes them more prone to obstruction than inguinal herniae.*





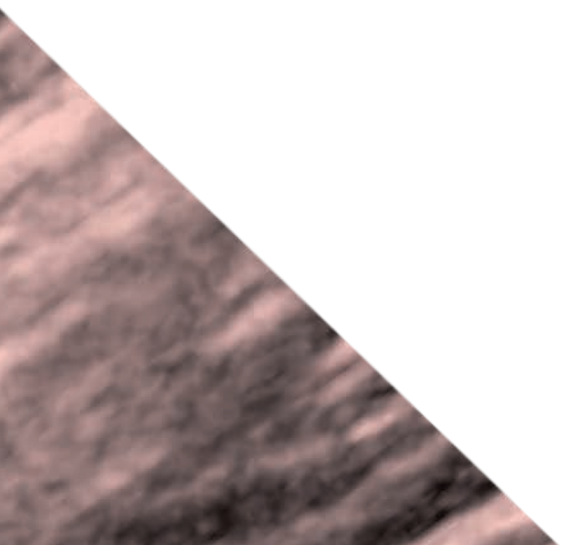
(Left) *Transverse ultrasound shows a left femoral hernia containing mesenteric fat. The neck of the hernia lies medial to the femoral vein and artery. The femoral nerve (not shown) lies lateral to the artery. **(Right)** Longitudinal ultrasound of the same femoral hernia shows that the neck of the hernia lies distal to the inguinal ligament. Femoral herniae are more common in elderly women; however, the most common hernia in women is still an indirect inguinal hernia.*



SECTION 1

General Lumps and Bumps

Hypoechoic Subcutaneous Mass **III**-1-2
Hyperechoic Subcutaneous Mass **III**-1-8
Hypoechoic Muscle Mass **III**-1-14
Hyperechoic Muscle Mass **III**-1-20
Cystic Soft Tissue Mass **III**-1-26
Calcified Soft Tissue Mass **III**-1-32
Hypervascular Soft Tissue Mass **III**-1-36



HYPOECHOIC SUBCUTANEOUS MASS

DIFFERENTIAL DIAGNOSIS

Common
- Lipoma
- Vascular Anomaly
- Epidermoid Cyst
- Peripheral Nerve Sheath Tumor

Less Common
- Vascular Leiomyoma
- Pilomatricoma
- Fibroma
- Glomus Tumor
- Lymph Node
- Hematoma
- Abscess
- Fat Necrosis
- Rheumatoid Nodule
- Foreign Body Granuloma
- Sweat Gland Tumor
- Metastasis
- Lymphoma
- Sarcoma
  - Dermatofibrosarcoma Protuberans

ESSENTIAL INFORMATION

Key Differential Diagnosis Issues
- Ensure lesion is confined to subcutaneous tissues
  - Site of occurrence has important implications for diagnosis & treatment
- Use minimal transducer pressure to avoid distorting lesion
  - Copious skin gel will allow stand-off effect if mass is producing cutaneous nodule
    - This is better than using gel pad, which will exert pressure on subcutaneous tissues
- Compressibility assessed by transducer pressure
  - Gives indication of firmness of mass, which is useful when distinguishing fatty from nonfatty tissue or inflammatory from noninflammatory tissue

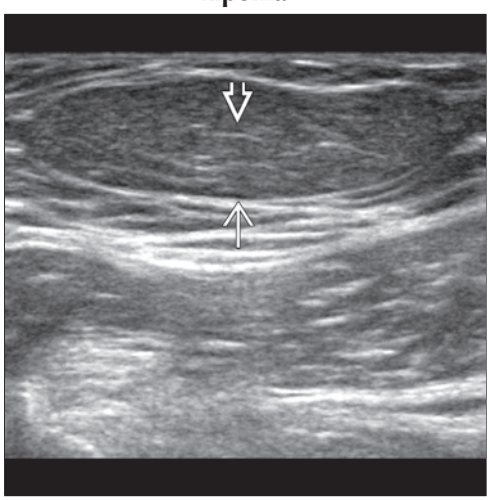
Helpful Clues for Common Diagnoses
- **Lipoma**
  - Variable echogenicity depending on cellularity & fat-water content
    - Usually are isoechoic to subcutaneous fat
    - Subcutaneous fat usually hypoechoic but this echogenicity can vary for different locations
  - Diagnosis (as always) depends on a constellation of findings rather than 1 single feature
    - Well-marginated, encapsulated, compressible mass with multiple fine distinctive echogenic lines parallel to skin surface
    - Usually no vascularity or only minimal vascularity on color Doppler imaging
- **Vascular Anomaly**
  - Comprises both hemangioma & vascular malformation
    - Differentiation based on cellular turnover, histologic features, & natural history
  - Variable ultrasound appearances
    - Mixed echogenicity depending on relative amount of fatty stroma or dilated vascular channels
    - Dilated vascular or lymphatic spaces may appear as hypoechoic vascular channels or large hypoechoic cystic spaces
    - Vascular anomalies with prominent vascular components appear hypoechoic
    - Vascularity varies from no detectable flow to very hypervascular depending on vessel type, size, & flow
    - Moderately compressible
    - ± phleboliths
    - ± slow venous flow best seen on real-time grayscale imaging
- **Epidermoid Cyst**
  - Ultrasound appearances depend on degree of cyst maturation & compactness of keratin ± presence of cyst rupture
  - Well-circumscribed, ovoid or lobulated mass with increased acoustic transmission
  - Most are heterogeneous
    - Linear, hyperreflective, disc-like areas represent layered keratin aggregates ± cholesterol deposition
    - Cleft-like or filiform anechoic or hypoechoic areas are due to cyst-like spaces lacking keratin
    - Less compact keratin → increased hypoechogenicity
  - Most epidermoid cysts are avascular
    - Peripheral & pericystic vascularity is feature of cyst rupture with pericystic inflammation
- **Peripheral Nerve Sheath Tumor**
  - Well-defined homogeneous hypoechoic mass
  - Occasionally heterogeneous
    - Heterogenicity due to areas of myxoid tissue, hemorrhage, fibrosis, or calcification
  - Fusiform-shaped along course of nerve
    - Entering or exiting nerve seen in majority of cases
    - Entering/exiting nerves may not be seen if arising from small cutaneous or subcutaneous nerve
  - Posterior acoustic enhancement is common
  - Usually moderate to high intrinsic vascularity

Helpful Clues for Less Common Diagnoses
- **Vascular Leiomyoma**
  - Benign, solitary smooth muscle neoplasm that most commonly occurs in subcutaneous soft tissues of lower extremity
  - Usually round or ovoid in shape with long axis parallel to extremity axis
  - Smooth-bordered, homogeneous, hypoechoic mass without perceivable capsule
  - Occurs in close proximity to artery or vein
  - Hypervascular with peripheral vascular convergence
- **Pilomatricoma**
  - Benign skin tumor arising from cells of hair matrix, more commonly seen in children
  - Well-circumscribed, ovoid, heterogeneous, solid subdermal mass containing matrix calcification, intrinsic vascularity, & peripheral hypoechoic rim
  - Hypoechoic peripheral rim due to connective tissue capsule
  - Intrinsic vascularity which may be peripheral, central, or mixed peripheral & central
- **Fibroma**
  - Localized tumorous collection of collagen with sparse number of fibroblasts
  - Well-defined to irregular hypoechoic mass
  - Minimal to mild intrinsic vascularity
- **Glomus Tumor**

- Arises from glomus body, which is arteriovenous shunt in dermis that contributes to temperature regulation
- Most common location: Distal extremities, especially subungual areas
- Small, well-defined, hypoechoic, hypervascular mass

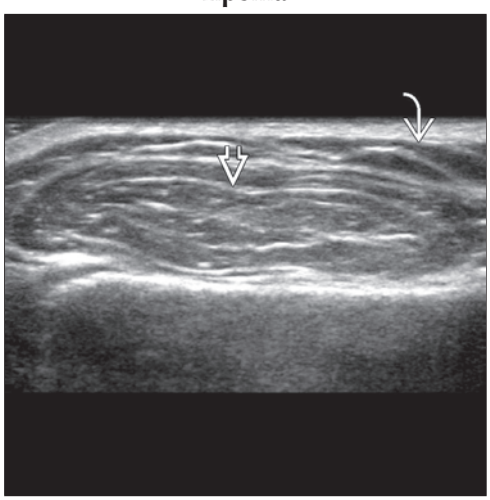
- **Lymph Node**
  - Enlarged subcutaneous nodes can be due to reactive, infective, metastatic, or lymphomatous nodes
  - Preserved central echogenic fatty hilum & hilar vascularity in reactive & infective nodes
  - Obliteration of central echogenic fatty hilum in metastatic or lymphoma node → hypoechoic mass
    - Variable peripheral vascularity or mixed hilar & peripheral flow pattern
- **Hematoma**
  - Usually echogenic in acute stages
  - Becomes hypoechoic after several days to weeks when liquefaction occurs
  - Occurs close to bony prominence
- **Abscess**
  - Usually hypoechoic but may be echogenic due to aggregates of inflammatory debris
  - Surrounding edema & hyperemia
  - Moving echoes on real-time imaging
- **Fat Necrosis**
  - Swelling & increased echogenicity of subcutaneous fat in early stages, which becomes more hypoechoic with increasing chronicity
    - ± liquefaction with discrete irregular hypoechoic areas
    - ± calcification
    - ± fat atrophy in later stages
- **Rheumatoid Nodule**
  - Extraarticular manifestation occurring in 10% of rheumatoid arthritis patients
  - Most common in subcutaneous tissue subjected to pressure with deep bony surface
    - Extensor surface of forearms, olecranon area, & finger joints
  - Well-defined, homogeneous, hypoechoic mass with no posterior shadowing
  - Minimal or mild intrinsic vascularity
- **Foreign Body Granuloma**
  - Variable thickness rim of hyperemic & hypoechoic granulation tissue forms around foreign body
    - Makes echogenic foreign body more conspicuous
- **Sweat Gland Tumor**
  - Tumor originates from either eccrine or apocrine sweat glands
  - Hypoechoic, heterogeneous nodule of low vascularity ± cystic areas
- **Metastasis**
  - 2.5% of superficial soft tissue are metastases
  - Most common (> 50%) from breast, bronchus, & melanoma
  - Roundish hypoechoic mass, well-demarcated, irregular margin
  - Mild to moderate intrinsic vascularity usually present
  - ± features of primary tumor (e.g., myxoid, calcification)
  - Melanoma metastases tend to be distinctly hypoechoic & may be elongated due to spread along lymphatic channels
- **Lymphoma**
  - Involvement of superficial tissues uncommon
  - Subcutaneous panniculitis-like T-cell lymphoma is uncommon type of peripheral T-cell lymphoma
- **Sarcoma**
  - 2.5% of superficial soft tissue masses are sarcoma
  - Large (> 5 cm), heterogeneous, hypoechoic mass
  - Usually hypervascular with disorganized vascular pattern on color Doppler imaging
  - Dissimilar to known benign subcutaneous tumors
  - **Dermatofibrosarcoma Protuberans**
    - Low-grade spindle cell mesenchymal sarcoma of dermis & subcutis
    - Most commonly arises in trunk (~ 50%), particularly chest wall, back, & abdominal wall
    - Well-marginated, lobulated, hypoechoic mass
    - Small echogenic speckles & larger discrete hypoechoic cleft-like areas within mass
    - Posterior enhancement
    - Central & peripheral organized vascularity

Lipoma



Longitudinal ultrasound shows an encapsulated ⇨ subcutaneous lipoma isoechoic to adjacent subcutaneous fat with fine internal echogenic striations ⇨ parallel to the long axis of the tumor.

Lipoma

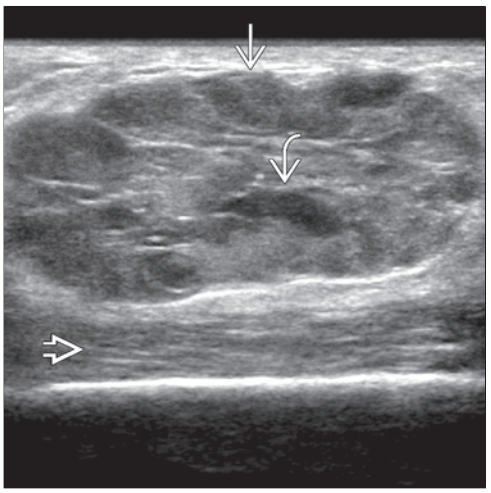


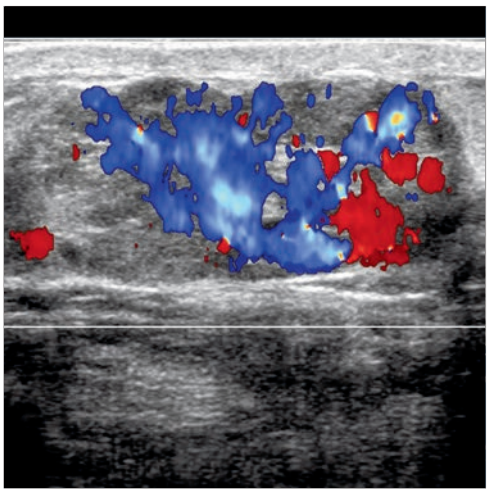
Longitudinal ultrasound of a subcutaneous lipoma shows prominent horizontal striations ⇨ aligned parallel to the surrounding skin. The echogenicity of the lipoma is similar to the hypoechoic subcutaneous fat ⇨.

HYPOECHOIC SUBCUTANEOUS MASS

Vascular Anomaly

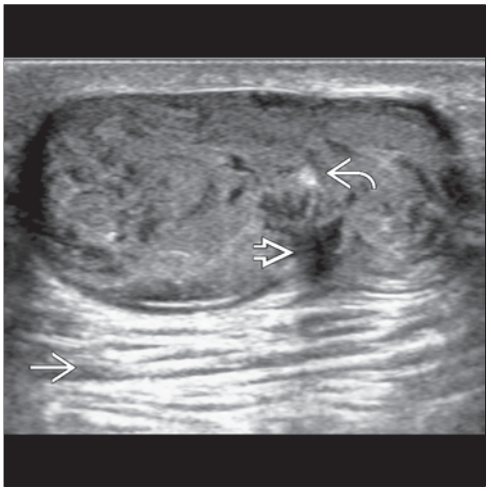
(Left) *Longitudinal ultrasound shows a well-defined, lobulated, hypoechoic mass lesion within the subcutaneous tissue without subfascial extension. There are tubular hypoechoic areas presenting dilated vascular channels within the mass. The muscle layer is intact.* ***(Right)*** *Longitudinal color Doppler ultrasound of the same lesion shows that it consists of venous-type vascular channels (50%) and supporting connective tissue stromal element (50%).*

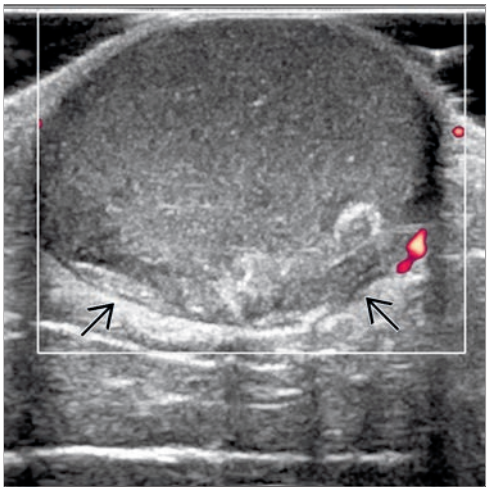




Epidermoid Cyst

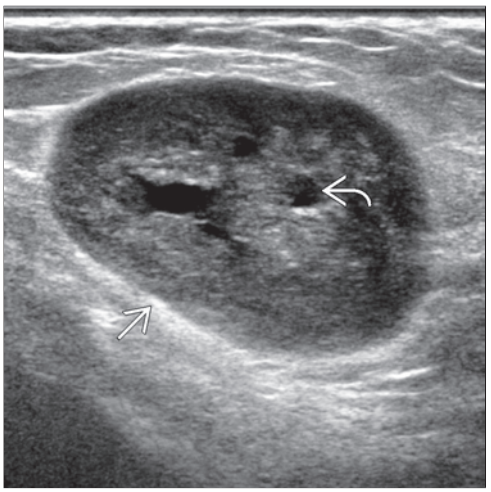
(Left) *Longitudinal ultrasound shows a well-defined, hypoechoic epidermoid cyst with multiple small anechoic areas representing cystic-like areas lacking keratin & small hyperechoic foci representing cholesterol deposits. Note the increased posterior acoustic transmission.* ***(Right)*** *Transverse ultrasound of another epidermoid cyst shows a more homogeneous hypoechoic appearance with less discrete cystic-like spaces & hyperechoic foci. No intrinsic vascularity is present.*

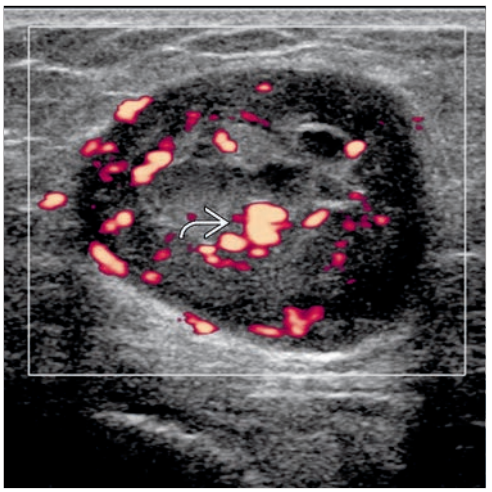




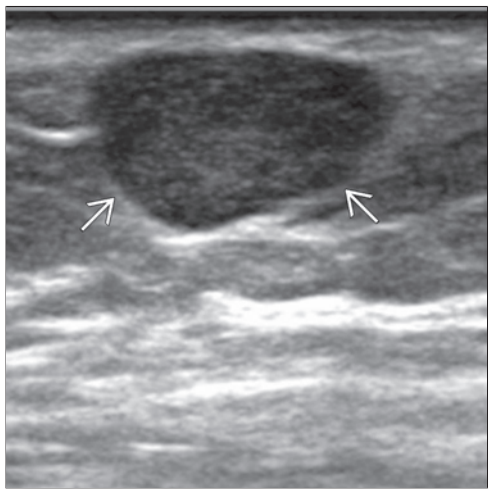
Peripheral Nerve Sheath Tumor

(Left) *Longitudinal ultrasound shows an oval, hypoechoic schwannoma containing multiple small cyst-like areas due to myxoid tissue. No entering or exiting nerve is evident. This absence of a visible parent nerve is a common feature of peripheral nerve sheath tumors arising from small cutaneous or subcutaneous nerves.* ***(Right)*** *Transverse power Doppler ultrasound of the same lesion shows a moderate degree of disorganized hyperemia.*

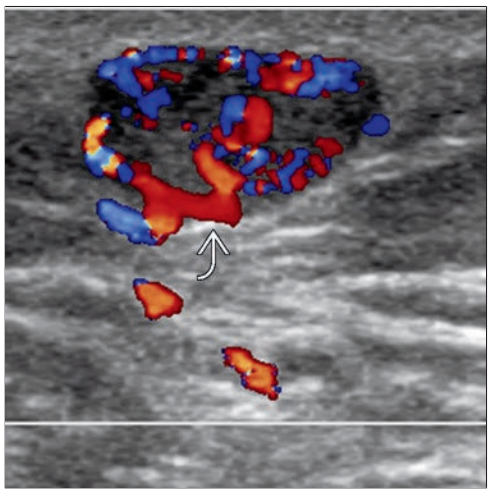




Vascular Leiomyoma

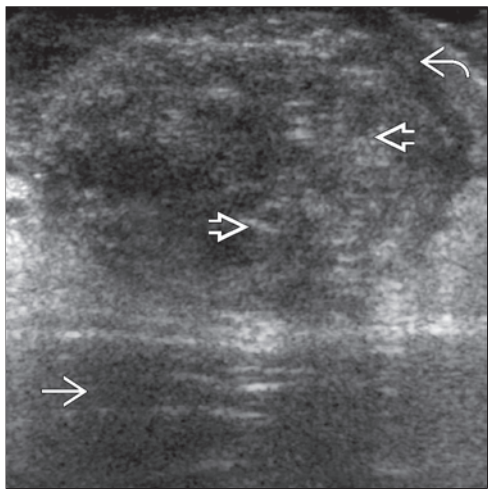


Vascular Leiomyoma

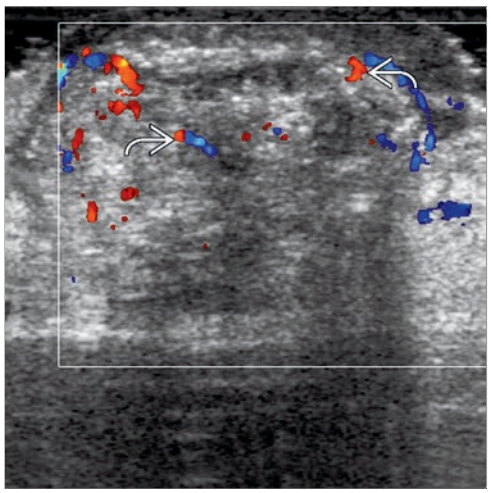


(Left) *Longitudinal ultrasound shows a well-defined, smooth bordered, homogeneous, hypoechoic mass in the subcutaneous tissue of the thigh. The long axis of the tumor is parallel to the axis of the lower limb.* ***(Right)*** *Longitudinal color Doppler ultrasound shows a moderate degree of organized hyperemia with peripheral vascular convergence to a point. This peripheral vascular convergence is a characteristic ultrasound feature of vascular leiomyoma.*

Pilomatricoma

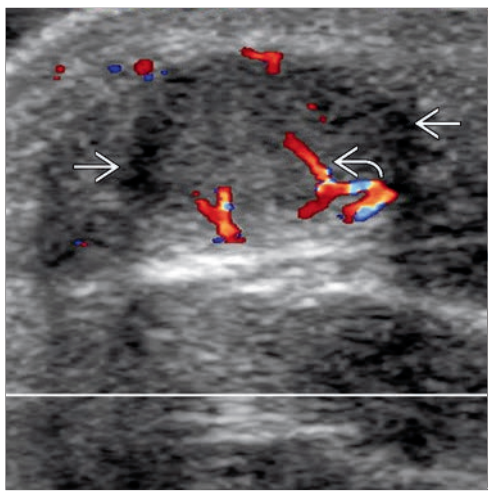


Pilomatricoma

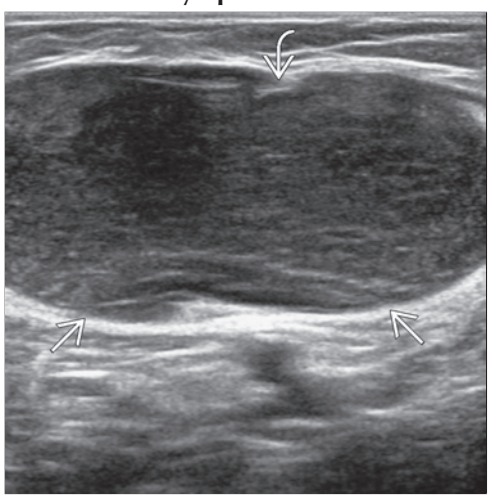


(Left) *Longitudinal ultrasound shows a heterogeneous, hypoechoic pilomatricoma containing multiple internal calcifications with mild posterior acoustic shadowing. There is a peripheral hypoechoic connective tissue capsule.* ***(Right)*** *Longitudinal color Doppler ultrasound of the same pilomatricoma shows a mild to moderate degree of disorganized intrinsic vascularity. Pilomatricoma is a benign tumor arising from cells of the hair matrix and is more commonly seen in children.*

Glomus Tumor



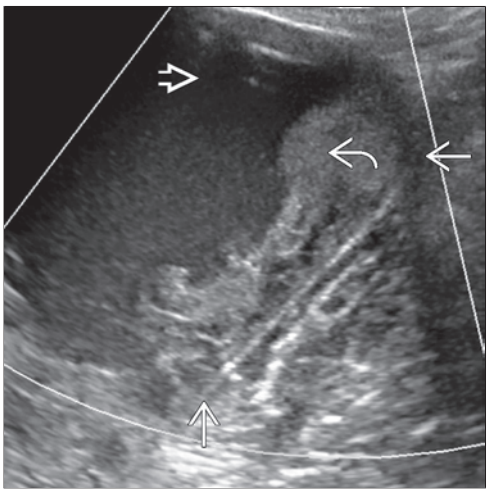
Lymph Node



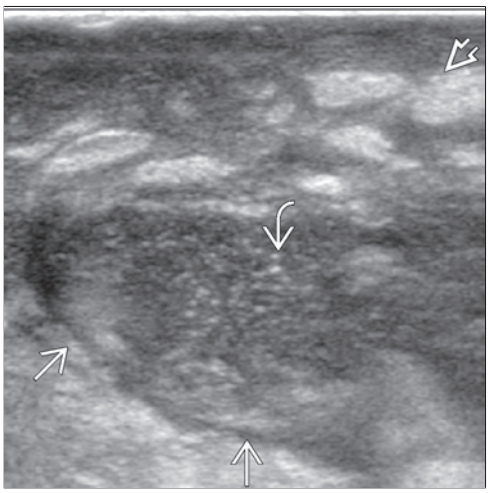
(Left) *Transverse color Doppler ultrasound shows a subcutaneous glomus tumor with a well-defined, smooth border. The tumor is homogeneously hypoechogenic with moderate intrinsic vascularity.* ***(Right)*** *Longitudinal ultrasound shows an enlarged subcutaneous lymph node on the medial aspect of the upper thigh. There is marked cortical hypertrophy with near complete obliteration of the echogenic fatty hilum. Percutaneous biopsy revealed a low-grade B-cell lymphoma.*

HYPOECHOIC SUBCUTANEOUS MASS

Hematoma

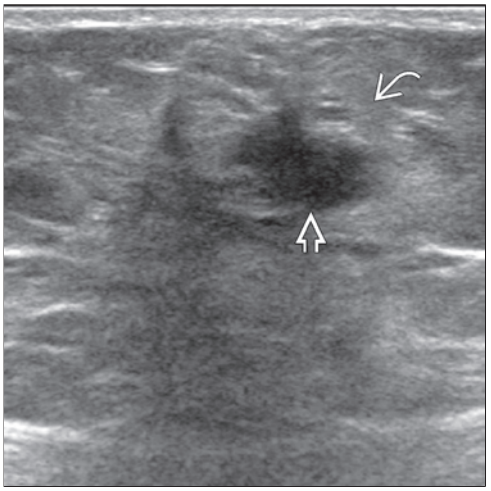


Abscess

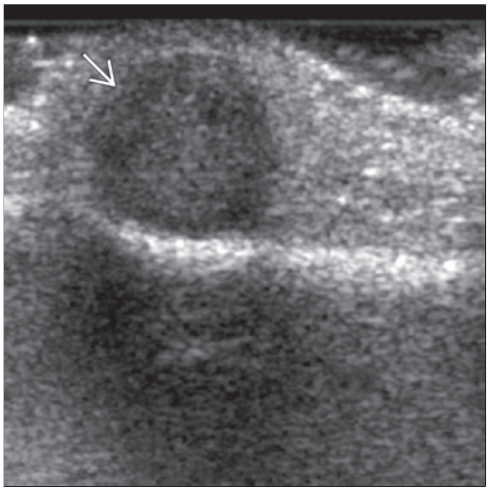


(Left) *Longitudinal ultrasound shows a subcutaneous hematoma with a large liquefied component and a small peripheral echogenic component. No intrinsic vascularity is evident.* ***(Right)*** *Transverse ultrasound shows a large, irregular subcutaneous abscess containing moderate echogenic internal debris. There is severe edema of the adjacent subcutaneous fat.*

Fat Necrosis

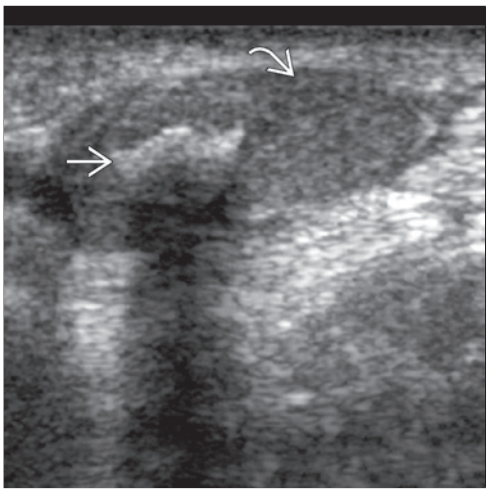


Rheumatoid Nodule

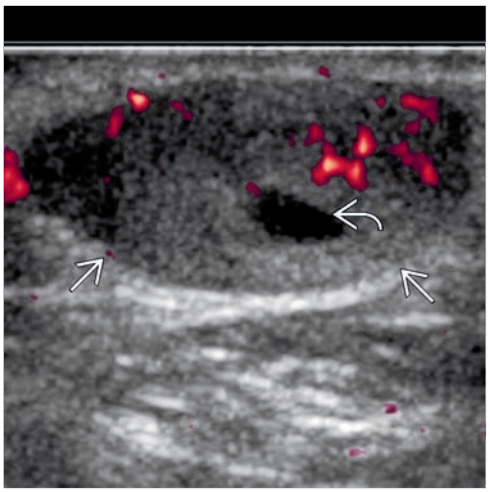


(Left) *Transverse ultrasound of post-traumatic fat necrosis shows a heterogeneous subcutaneous mass composed of ill-defined peripheral hyperechoic and a discrete central hypoechoic component. Areas of established subcutaneous fat necrosis become better defined & more hypoechoic with increasing chronicity.* ***(Right)*** *Oblique ultrasound shows a round, hypoechoic rheumatoid nodule in the finger of a patient with rheumatoid arthritis. No cystic area is seen.*

Foreign Body Granuloma



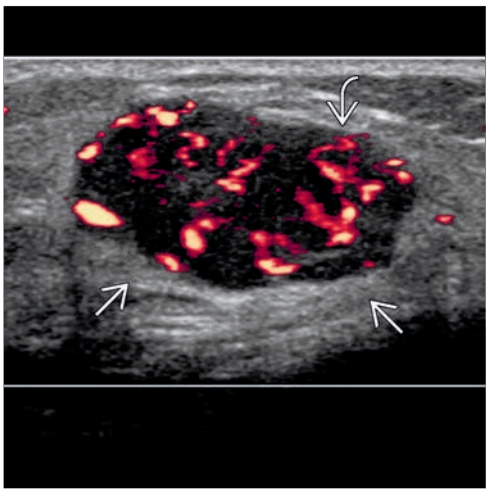
Sweat Gland Tumor



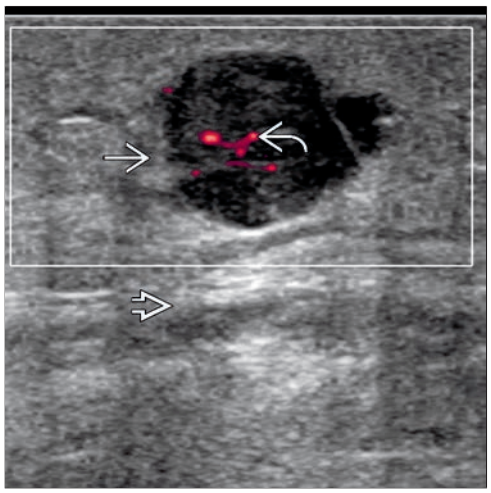
(Left) *Longitudinal ultrasound shows a subcutaneous foreign body granuloma of the forearm. The hyperechoic retained glass fragment is surrounded by a thick, hypoechoic rim of granulation tissue. The mass was moderately vascular on color Doppler imaging (not shown).* ***(Right)*** *Longitudinal power Doppler ultrasound shows a well-defined, ovoid, hypoechoic solid mass with a small cystic area and mild intrinsic vascularity. Excision revealed an eccrine spiradenoma.*

HYPOECHOIC SUBCUTANEOUS MASS

Metastasis

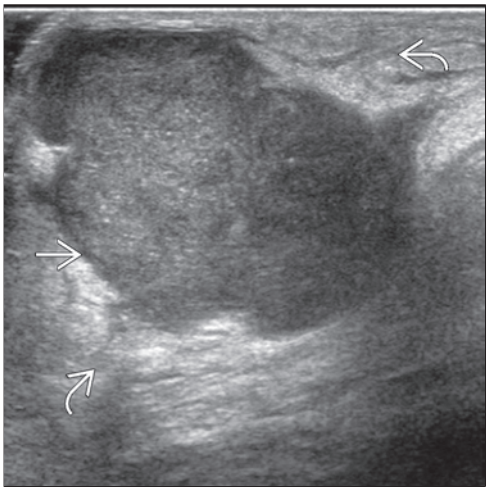


Metastasis

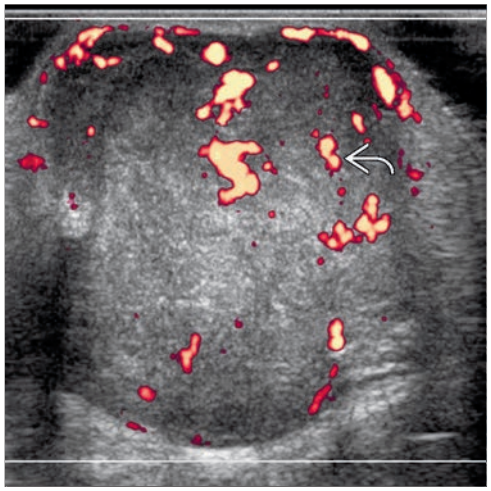


(Left) *Longitudinal power Doppler ultrasound shows a subcutaneous melanoma metastasis ➔ with moderate hyperemia. There is mild adjacent soft tissue edema ➔. **(Right)** Transverse power Doppler ultrasound shows a subcutaneous metastasis ➔ of the anterior abdominal wall from a malignant nerve sheath tumor in the calf. The mass is irregular & hypoechoic with mild posterior acoustic enhancement ➔ & mild hyperemia ➔.*

Sarcoma

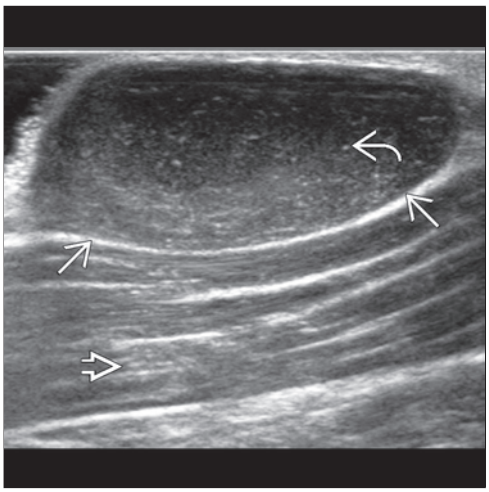


Sarcoma

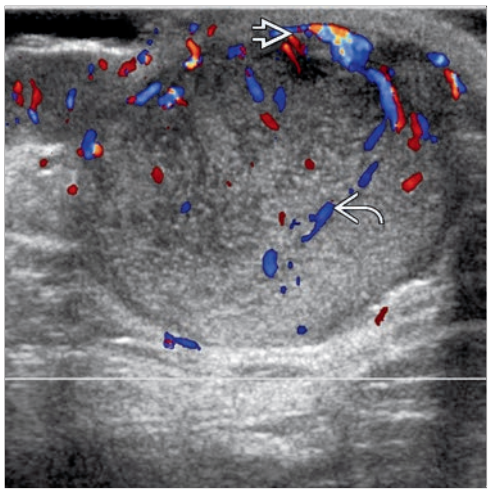


(Left) *Longitudinal ultrasound shows a large, irregular, hypoechoic subcutaneous mass ➔. The adjacent subcutaneous tissue is moderately edematous ➔. **(Right)** Transverse power Doppler ultrasound of the same lesion shows moderate intrinsic vascularity ➔. Percutaneous biopsy for histology revealed a fibrous histiocytoma. Superficial sarcoma is rare. The ultrasound appearances are unlike those of recognizable benign superficial tumors.*

Sarcoma



Sarcoma



(Left) *Longitudinal ultrasound shows a well-defined, fusiform-shaped, hypoechoic mass ➔ causing focal skin protuberance. It contains multiple fine echogenic speckles ➔ & shows mild increase in posterior acoustic transmission ➔. These are quite characteristic appearances of dermatofibrosarcoma protuberans. **(Right)** Transverse color Doppler ultrasound of dermatofibrosarcoma protuberans shows a moderate degree of organized central ➔ and peripheral ➔ vascularity.*

HYPERECHOIC SUBCUTANEOUS MASS

DIFFERENTIAL DIAGNOSIS

Common
- Lipoma
- Vascular Anomaly
- Epidermoid Cysts

Less Common
- Cellulitis
- Fat Necrosis
- Hematoma
- Panniculitis
- Pilomatricoma
- Abscess
- Gouty Tophus
- Granuloma & Fibroma
- Normal Lymph Node
- Fibrous Hamartoma of Infancy

ESSENTIAL INFORMATION

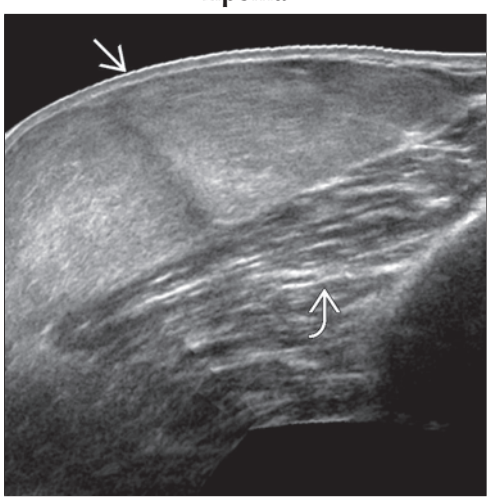
Key Differential Diagnosis Issues
- Use light transducer pressure
  - Any compression of subcutaneous fat will usually tend to make soft subcutaneous masses less conspicuous
- Subcutaneous fat may vary from hyperechoic to hypoechoic depending on location
- In some regions, particularly the gluteal region, subcutaneous fat looks similar to muscle
  - Take care in defining correct layer as this has important diagnostic and surgical implications

Helpful Clues for Common Diagnoses
- **Lipoma**
  - Variable echogenicity depending on cellularity and fat-water content but, in general, isoechoic to fat and hyperechoic to muscle
  - Well-marginated, encapsulated, compressible, fusiform-shaped mass
    - Multiple fine, distinctive echogenic lines parallel to skin surface
    - Some subcutaneous lipomas may be more uniform, rounded, and possess less distinct striation, particularly those which are multiple and located in trunk or proximal appendicular skeleton
    - Usually no detectable vascularity on color Doppler imaging
    - Consider angiolipoma if intrinsic vascularity detected
  - Lipohypertrophy = localized increase in fat accumulation, subcutaneous > > intermuscular
    - Increase in size of fat lobules and depth of subcutaneous fat
    - Usually affects middle-aged women
    - Absence of distinct border or capsule allows distinction of lipohypertrophy from lipoma
- **Vascular Anomaly**
  - Comprises both hemangioma and vascular malformation
    - Differentiation based on cellular turnover, histologic features, and natural history
  - Hemangioma
    - Benign vascular tumors of infancy and childhood with cellular proliferation and hyperplasia
    - Grows after birth, proliferates, and then involutes
  - Vascular malformation
    - Is due to vascular dysplasia rather than actual tumor with normal endothelial turnover
    - Present at birth and grows commensurately with child without proliferation or involution
    - Classified according to predominant vessel type as either venous, capillary, arterial, lymphatic, or combined type
  - Variable ultrasound appearances
    - Mixed echogenicity depending on relative fatty stromal or vascular components
    - Dilated vascular spaces may appear as hypoechoic vascular channels or large hypoechoic cystic spaces (venous lakes)
    - Variable stromal connective tissue component with predominant fatty-type background → appears hyperechoic
    - This echogenic stroma component may contain numerous capillaries too small to be resolved with ultrasound
    - Vascularity of vascular anomaly varies from no detectable flow → very hypervascular
    - Moderately compressible
    - ± phleboliths (mainly slow-flow anomalies)
- **Epidermoid Cysts**
  - Slow-growing subdermal cyst that contains keratin and is lined by stratified squamous epithelium but does not contain dermal elements
  - Ultrasound appearances depend on cyst maturation and compactness of keratin ± presence of cyst rupture
  - Most are well circumscribed, ovoid or lobulated
  - Increased acoustic transmission
  - Most are heterogeneous and mildly hyperechoic
  - Linear, hyperreflective, disc-like areas represent layered keratin aggregates ± cholesterol deposition
  - Cleft-like or filiform anechoic or hypoechoic areas are due to cyst-like spaces lacking keratin
  - Hypoechoic stalk-like punctum extending from superficial wall of cyst to skin seen in 10% of those referred for ultrasound examination
    - Most cysts with clinically apparent puncta are diagnosed clinically and not referred for ultrasound examination
  - Most epidermoid cysts are avascular
    - Peripheral and pericystic vascularity is feature of cyst rupture with pericystic inflammation

Helpful Clues for Less Common Diagnoses
- **Cellulitis**
  - Infection of subcutaneous fat
    - Characterized by edema and hyperemia
  - Group A *Streptococcus* and *Staphylococcus aureus* organisms are usually responsible
  - Subcutaneous fat is more echogenic when edematous
  - Subcutaneous edema = nonspecific finding seen with many conditions
    - Heart failure, venous insufficiency, immobility, and dependency
  - Cellulitis should have combination of edema and hyperemia
    - Thickened interlobular septa
    - ± periseptal fluid or fluid above investing fascia
  - Phlegmon = localized, intense inflammation of subcutaneous fat prior to development of abscess
- **Fat Necrosis**
  - Swelling of subcutaneous fat in early stages

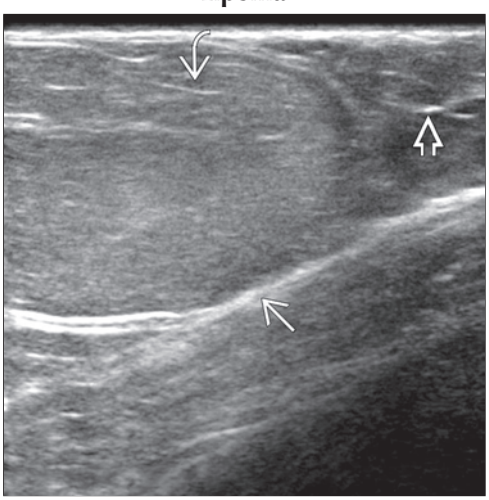
    - Hyperechoic edematous fat with loss of normal echogenic striation
    - Majority are due to previous trauma
  - Subcutaneous fat becomes more hypoechoic with increasing chronicity
    - ± liquefaction with discrete irregular hypoechoic areas
    - ± calcification
    - ± fat atrophy in later stages
    - Investing fascia and muscle is usually unaffected
- **Hematoma**
  - Echogenic in acute stages
  - ± circular echogenic layering due to sequential deposition of hemorrhage
  - ± linear layering due to separation of cellular and serous components
  - ± moving echoes on real-time imaging
  - ± liquefaction after several days to weeks
  - ± calcification as late feature
- **Panniculitis**
  - Localized inflammation of subcutaneous fat; has many causes
    - Idiopathic, infection, systemic inflammatory disorder, myeloproliferative disorder (panniculitis-like T-cell lymphoma), pancreatic disease, drug hypersensitivity, or Weber-Christian disease
  - Active stage: Localized area of increased echogenicity and thickness of subcutaneous fat with mild to moderate hyperemia
  - Inactive stage: Atrophy and hypoechogenicity of subcutaneous fat with little or no hyperemia
- **Pilomatricoma**
  - Benign skin tumor arising from cells of hair matrix
  - Mass extending from dermal to subdermal tissues
  - Well-circumscribed, ovoid, heterogeneous, solid subdermal mass with matrix calcification, intrinsic vascularity, and peripheral hypoechoic rim
  - Hypoechoic peripheral rim due to connective tissue capsule
  - Intrinsic vascularity may be peripheral, central, or mixed peripheral and central
- **Abscess**
  - May be echogenic due to aggregates of inflammatory debris
  - Surrounding edema and hyperemia
  - ± moving echoes on real-time imaging
- **Gouty Tophus**
  - Soft or hard tophi depending on concentration of crystals deposited
    - Soft tophi: Echogenic with mild to moderate posterior acoustic shadowing
    - Hard tophi: Echogenic with strong posterior acoustic shadowing
- **Granuloma & Fibroma**
  - Common in gluteal region
    - Frequently follow subcutaneous injection
  - May also occur elsewhere without any recognizable cause
  - Usually hypoechoic though occasionally hyperechoic
    - Often calcified
- **Normal Lymph Node**
  - May appear echogenic if large central fatty hilum and thin hypoechoic cortex present
    - Particularly in axillary nodes and subcutaneous lymph node on medial aspect of proximal thigh
- **Fibrous Hamartoma of Infancy**
  - Uncommon benign superficial fibrous tumor found in early childhood (< 2 years)
  - More common in boys
  - Mainly affects trunk, axilla, and upper extremities
  - Associated with skin pigmentation, hypertrichosis, and eccrine gland hyperplasia
  - Consist of mixture of fibrocollagenous tissue, primitive mesenchymal cells, and mature fat
    - Ultrasound appearances depend on proportion of these 3 components
  - Ill-defined heterogeneous, predominantly hyperechoic, subcutaneous mass
  - Usually no significant intrinsic vascularity
  - May involve investing fascia but subfascial extension is rare

Lipoma



Longitudinal ultrasound with extended field-of-view shows a large, hyperechoic subcutaneous lipoma ➔ causing bulging of the skin contour. The underlying deltoid muscle is normal ➔.

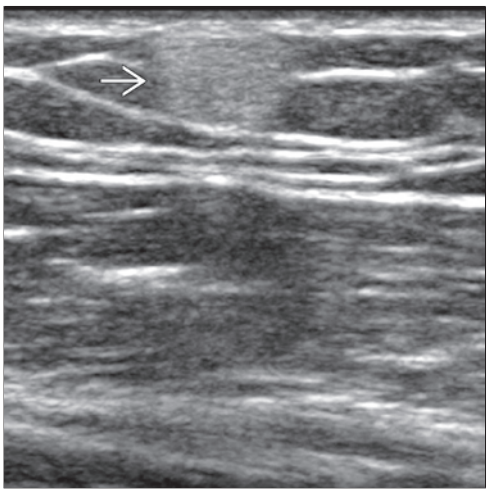
Lipoma



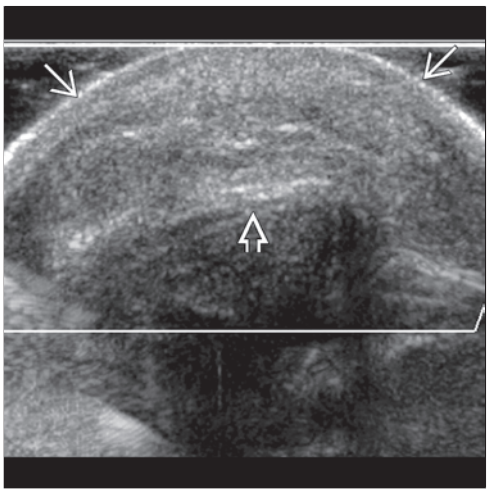
Longitudinal ultrasound shows an encapsulated subcutaneous lipoma abutting the investing fascia ➔. The lipoma is hyperechoic to adjacent subcutaneous fat ➔ with fine linear horizontal striations ➔.

HYPERECHOIC SUBCUTANEOUS MASS

Lipoma

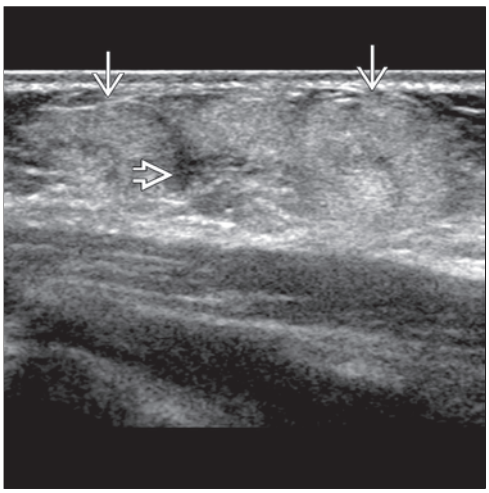


Vascular Anomaly

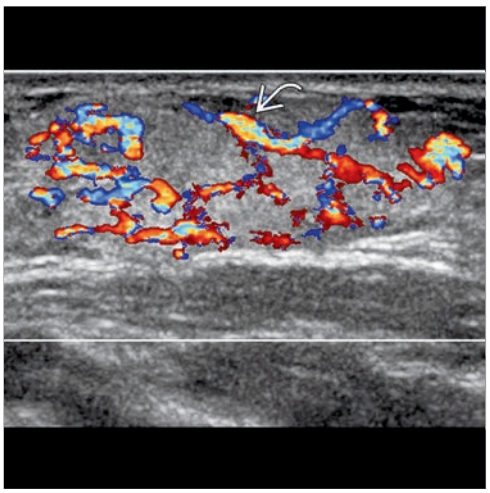


(Left) *Longitudinal ultrasound shows a small, rounded, well-defined, hyperechoic subcutaneous lipoma* ➔ *without perceivable linear striation. Such lipomas are often multiple and tend to be located more in the truck region than in the limbs.* ***(Right)*** *Transverse color Doppler ultrasound of child with pre-patellar* ➔ *bluish skin discoloration shows an echogenic subcutaneous mass* ➔ *without detectable intrinsic vascularity, consistent with a slow-flow vascular anomaly with a predominant stromal component.*

Vascular Anomaly

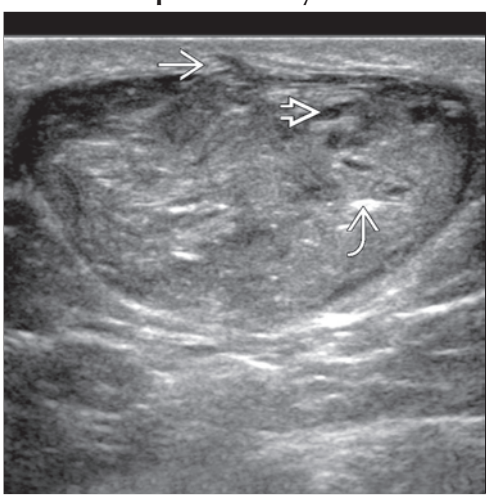


Vascular Anomaly

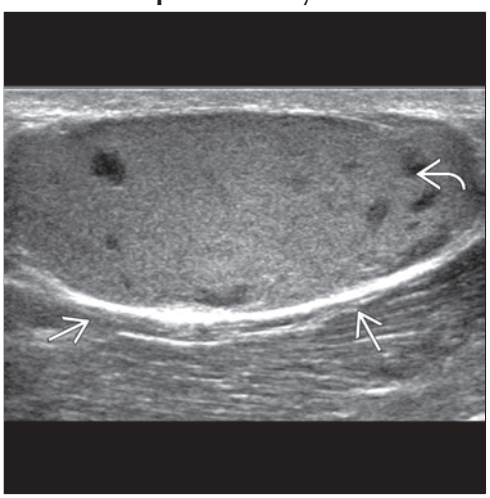


(Left) *Transverse color Doppler ultrasound of a 4-month-old infant shows a subcutaneous hemangioma* ➔ *with an echogenic fatty stroma. Note the hypoechoic vascular channels* ➔ *within the fatty stroma.* ***(Right)*** *Transverse color Doppler ultrasound of the same lesion shows multiple arterial vascular channels* ➔ *embedded within the fatty stroma. This fatty stroma may contain capillaries too small to be resolved on ultrasound and only seen on histological analysis.*

Epidermoid Cysts



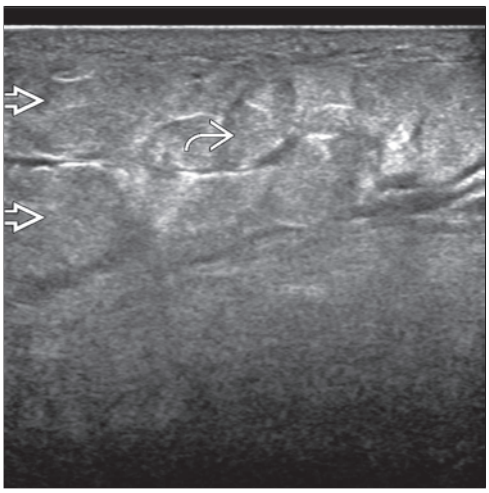
Epidermoid Cysts



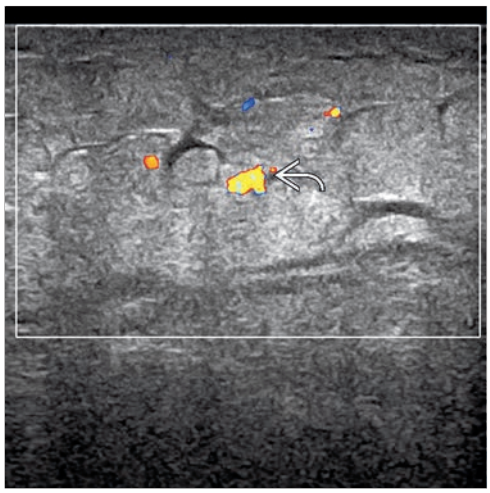
(Left) *Longitudinal ultrasound shows typical appearances of an epidermoid cyst with heterogeneous echotexture, dermal attachment, internal floating hyperreflective strands* ➔, *small hypoechoic areas* ➔, *and a hypoechoic track extending to a cutaneous punctum* ➔. ***(Right)*** *Longitudinal ultrasound shows an echogenic epidermoid cyst* ➔. *The mass is quite homogeneous with scattered internal hypoechoic areas* ➔ *representing cyst-like spaces lacking keratin.*

HYPERECHOIC SUBCUTANEOUS MASS

Cellulitis

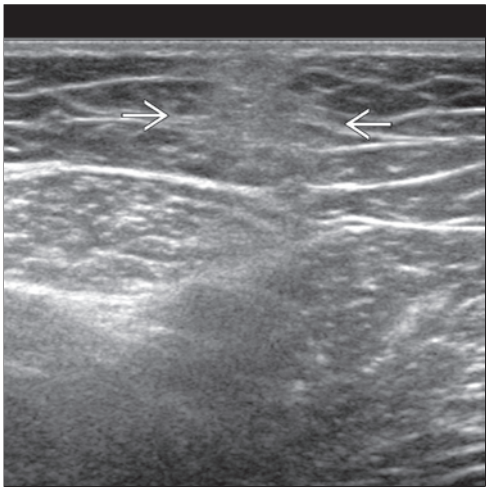


Cellulitis

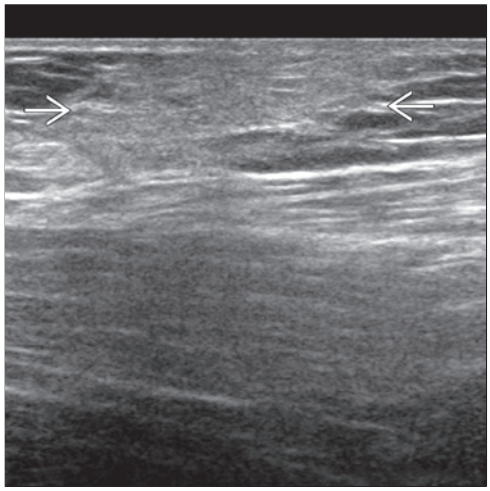


(Left) *Transverse ultrasound of the ankle region shows severe subcutaneous edema with diffuse increased echogenicity of the subcutaneous fat. The fat lobules are indistinct.* ***(Right)*** *Transverse color Doppler ultrasound of the same patient shows mild hyperemia of the subcutaneous tissues overall, consistent with moderate-severity cellulitis. Hyperemia helps differentiate cellulitis from noninfective causes of ankle edema such as heart failure.*

Fat Necrosis

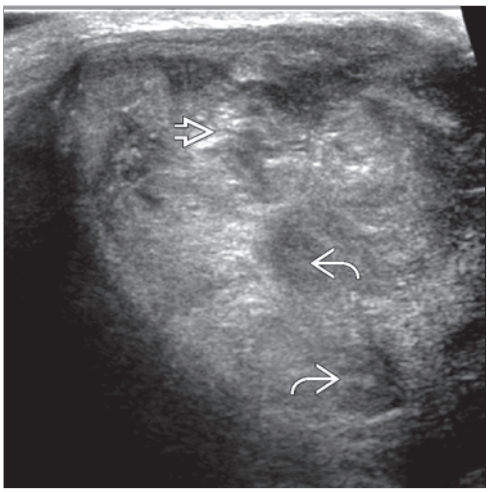


Fat Necrosis

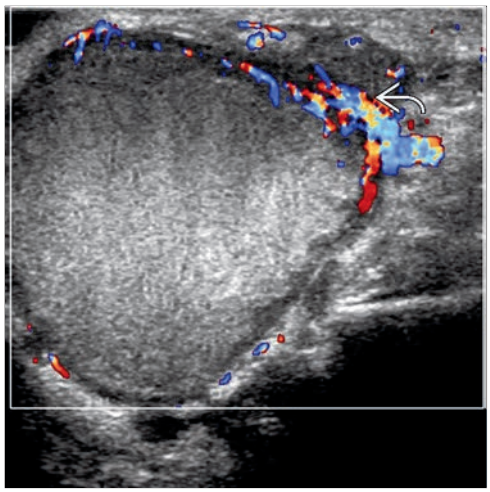


(Left) *Transverse ultrasound of the lateral thigh region in a patient with recent trauma to this area shows an ill-defined area of increased echogenicity of the subcutaneous fat.* ***(Right)*** *Longitudinal ultrasound of the same lesion shows an area of hyperechogenicity consistent with post-traumatic subcutaneous edema. There is no mass effect. As the lesion became chronic, the echogenicity decreased and the subcutaneous fat focally atrophied to a mild degree, all consistent with subcutaneous fat necrosis.*

Hematoma



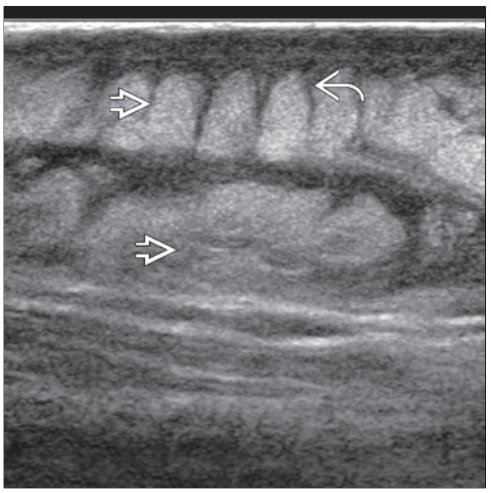
Hematoma



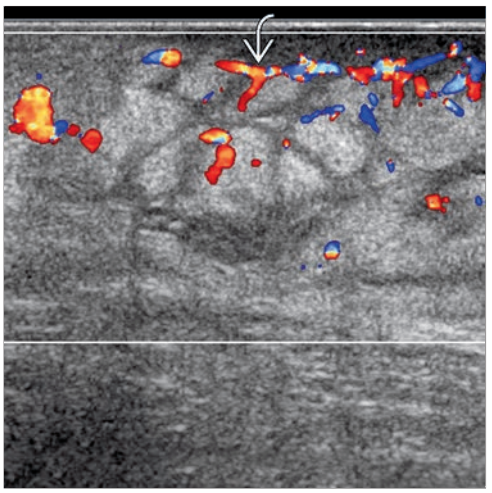
(Left) *Transverse ultrasound shows an organizing hematoma in the subcutaneous tissue above the iliac crest. The lesion is echogenic with several intrinsic whorl-like patterns and echogenic strands.* ***(Right)*** *Transverse color Doppler ultrasound shows a subcutaneous organizing hematoma in the forearm. The mass is quite homogeneous with a peripheral, hypoechoic, moderately vascularized fibrous capsule.*

HYPERECHOIC SUBCUTANEOUS MASS

Panniculitis

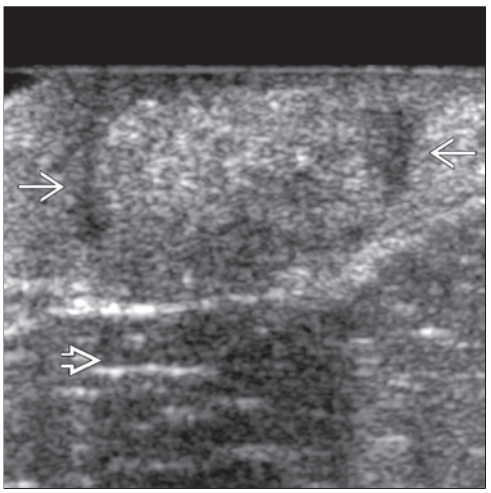


Panniculitis

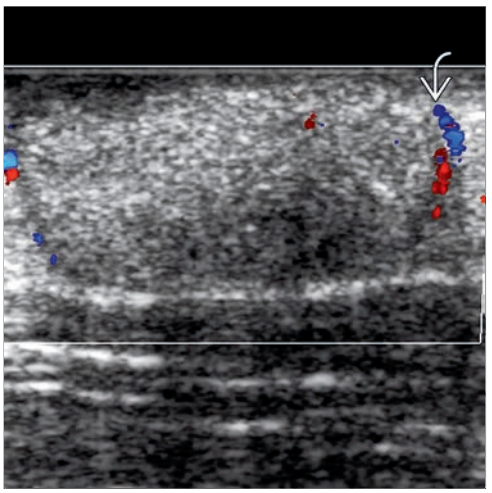


(Left) *Longitudinal ultrasound of an immunocompromised patient with fever and leg swelling shows focal subcutaneous edema with multiple prominent echogenic fat lobules separated by hypoechoic septi.* ***(Right)*** *Transverse color Doppler ultrasound shows moderate to severe hyperemia of the inflamed subcutaneous fat due to infective panniculitis. The focal nature of panniculitis distinguishes it from more diffuse cellulitis.*

Pilomatricoma

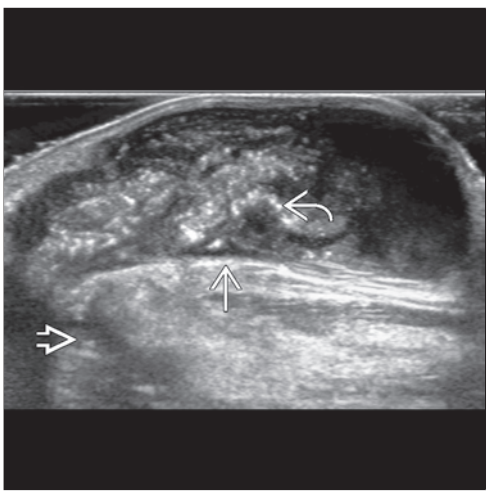


Pilomatricoma

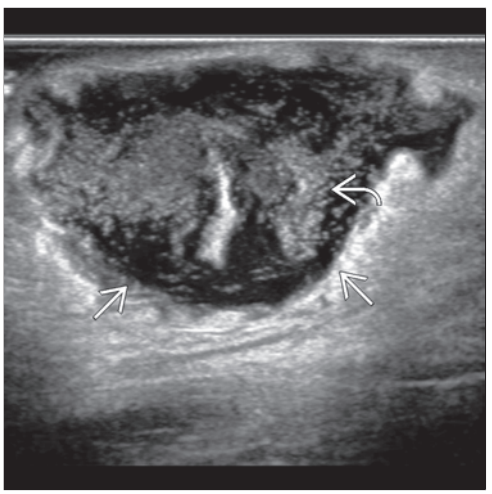


(Left) *Transverse ultrasound shows a well-defined, mixed echogenic pilomatricoma in the subcutaneous tissues. There are multiple scattered echogenic foci with mild posterior shadowing due to matrix calcification.* ***(Right)*** *Longitudinal color Doppler ultrasound of the same lesion shows mild hyperemia of the peripheral hypoechoic rim.*

Abscess



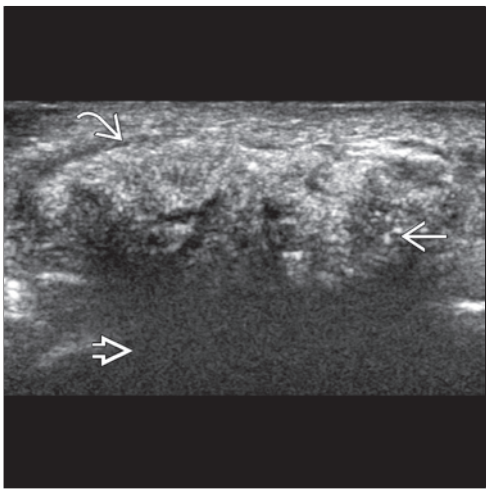
Abscess



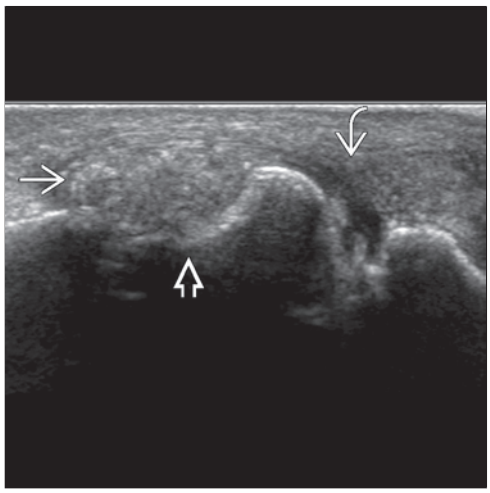
(Left) *Longitudinal ultrasound of the finger shows a large heterogeneous tuberculous cold abscess with internal calcification and moving echoes (on real-time imaging). This abscess extends from the metacarpophalangeal joint into the subcutaneous tissues.* ***(Right)*** *Transverse ultrasound of the arm shows an irregular pyogenic abscess with internal echogenic debris, seen to move on real-time imaging. Microbiology grew Enterococcus and Acinetobacter species.*

HYPERECHOIC SUBCUTANEOUS MASS

Gouty Tophus

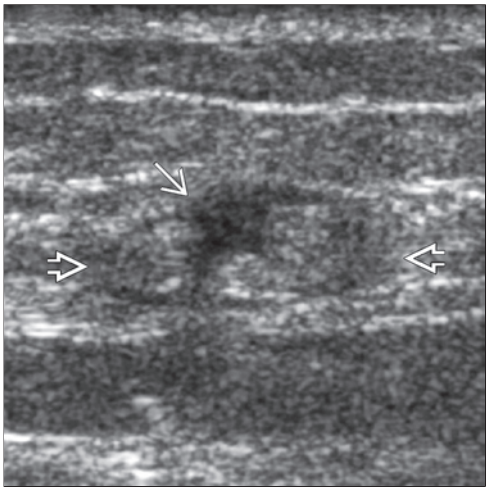


Gouty Tophus

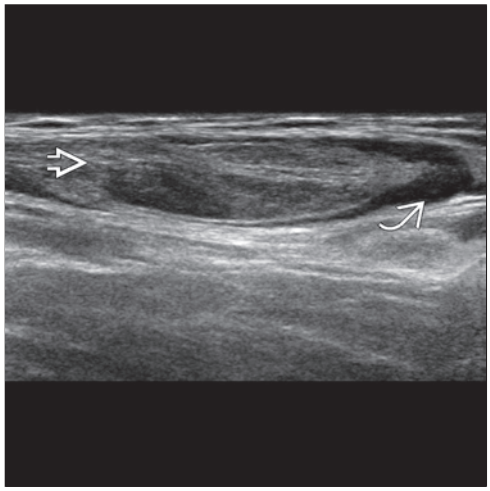


(Left) *Longitudinal ultrasound shows an echogenic gouty tophus in the subcutaneous tissues overlying the 3rd metatarsophalangeal joint. There are "comet tail" artifacts present with posterior acoustic shadowing. **(Right)** Longitudinal ultrasound shows a soft tophus associated with marginal erosion of the 1st metatarsal head. A small metatarsophalangeal joint effusion is present with echogenic gouty crystal aggregates.*

Granuloma & Fibroma

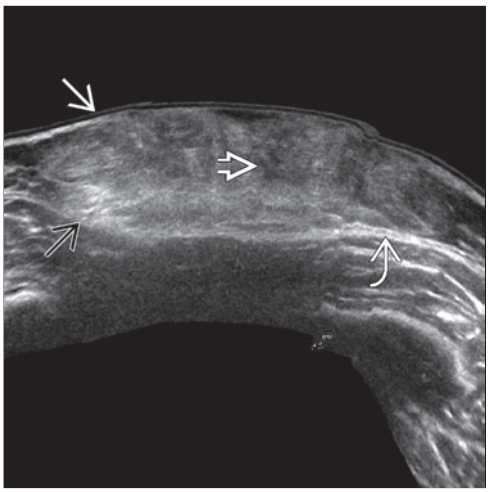


Normal Lymph Node

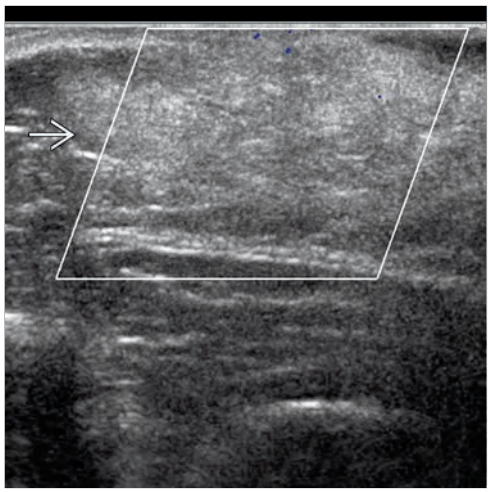


(Left) *Transverse ultrasound shows a subcutaneous injection granuloma in the buttock region. The granuloma is heterogeneous with a central hypoechoic area surrounded by hyperechoic tissue. This appearance is probably due to a combination of mature (hypoechoic) and immature (hyperechoic) granulation tissue. **(Right)** Longitudinal ultrasound shows a normal deep inguinal lymph node (Cloquet node) with a large central fatty hilum and a thin peripheral hypoechoic cortex.*

Fibrous Hamartoma of Infancy



Fibrous Hamartoma of Infancy



(Left) *Longitudinal ultrasound with extended field-of-view of an anterior thigh mass in an infant shows an ill-defined hyperechoic, heterogeneous subcutaneous mass abutting but not traversing the investing fascia. The hyperechoic component represents mature fat while the hypoechoic component represents fibrous tissue. **(Right)** Transverse color Doppler ultrasound of the same lesion shows no intrinsic vascularity.*

HYPOECHOIC MUSCLE MASS

DIFFERENTIAL DIAGNOSIS

Common
- Hematoma
- Muscle Tear
- Nerve Sheath Tumor

Less Common
- Soft Tissue Sarcoma
- Myxoma
- Fibromatosis
- Abscess
- Metastases
- Lymphangioma
- Intramuscular Extension of Baker Cyst
- Vascular Malformation
- Local Recurrence
- Intramuscular Ganglion Cyst
- Granuloma
- Diabetic Muscle Infarction

Rare but Important
- Parasitic Infection

ESSENTIAL INFORMATION

Key Differential Diagnosis Issues
- Clinical history is important for differentiating any muscle mass
- Acute hematoma and infection are usually readily distinguishable from other muscle masses
- Make every effort to reach diagnosis before resorting to percutaneous biopsy or aspiration
  - Often percutaneous biopsy is not necessary
  - However, if unsure regarding nature of mass, arrange either follow-up or biopsy, or request alternative investigation (usually MR)

Helpful Clues for Common Diagnoses
- **Hematoma**
  - Due to trauma, anticoagulation, or vascular malformation
  - Anterior thigh is common location because it is susceptible to compression injury against femoral shaft and muscle contraction injury
  - Initially hyperechoic or isoechoic
    - Becomes more hypoechoic with increasing liquefaction after several days to weeks
    - ± layering or whorled pattern due to sequential episodes of bleeding (expanding hematoma)
  - Mild intramuscular hemorrhage may not be apparent on US, since ill-defined hyperechoic areas of blood blend with hyperechoic muscle
    - No disturbance of muscle architecture with minor bleeding
    - MR is more sensitive than ultrasound at detection of tumor hemorrhage
- **Muscle Tear**
  - Discontinuity ± retraction of muscle fibers within muscle bulk or at myofascial junction
    - Myofascial junction most common site of tear
  - ± tear filled with hematoma or fluid
  - ± surrounding muscle and subcutaneous edema
  - Do not confuse with muscle contusion
    - Contusion shows no fiber discontinuity
    - May cross muscle fascial boundaries
    - Ill-defined hyperechogenicity of muscle due to edema ± blood
    - Hyperemia during reparative stage
- **Nerve Sheath Tumor**
  - Arises along course of peripheral nerve
  - Well-defined, fusiform-shaped, hypoechoic mass
    - Anechoic areas due to myxoid accumulation (common)
    - ± additional areas of hyperechogenicity due to hemorrhage, calcification, or fibrosis
  - Posterior acoustic enhancement (mild to moderate)
  - Thickened entering or exiting nerve (very common)
    - Entering or exiting nerve may not be visible if tumor arises from small peripheral nerve
  - "Split-fat" sign due to separation of muscle fibers with enhanced visibility of fat at edge of tumor
    - Do not confuse with thickened nerve at edge of tumor
  - Mild to moderate hyperemia on color Doppler
    - Very occasionally, minimal demonstrable vascularity
  - Cannot differentiate between schwannoma and neurofibroma based on ultrasound findings alone
  - Try, however, to determine whether nerve is centrically or eccentrically placed relative to parent nerve

Helpful Clues for Less Common Diagnoses
- **Soft Tissue Sarcoma**
  - Usually seen as large, well-defined, hypoechoic mass within muscle layer
    - Moderately to highly vascular
    - Occasionally hypovascular or even avascular on color Doppler imaging
    - Hypovascularity does not exclude malignancy
  - Any large (> 5 cm), solid, nonfatty, soft tissue tumor should be considered sarcoma unless proven otherwise by biopsy
    - Most large intramuscular masses require biopsy
    - Biopsy not very helpful in differentiating well-differentiated liposarcoma from lipoma
    - Better to decide likelihood of liposarcoma by clinical and MR criteria as well as histological analysis of full tumor following excision
- **Myxoma**
  - Composed of a few spindle-shaped cells within mucoid material supported by loose collagen framework
    - Derived from modified fibroblasts with increased proteoglycan production
  - Hypoechoic, cystic-type, intramuscular mass ± "comet tail" artifacts
    - Peripheral rim of increased echogenicity ("bright rim" sign), corresponding to perilesional muscle edema
    - Triangular hyperechoic area adjacent to mass ("bright cap" sign), corresponding to muscle atrophy
    - No communication with adjacent joint
    - Main differential diagnosis is myxoid liposarcoma
- **Fibromatosis**
  - Also known as desmoid tumor
  - Locally aggressive overgrowth of fibrous tissue with well-defined or infiltrative border
    - Typically absent or minimal vascularity on color Doppler imaging
- **Abscess**

- More frequent in immunosuppressed patients
- Many variable appearances
- Thick-walled, irregular hypervascular outline with hypoechoic, avascular necrotic center (typical)
  - + edema and hyperemia of adjacent inflamed tissues
  - ± intralesional gas locules seen to move on real-time imaging
  - ± enlarged regional lymph nodes
- Ultrasound-guided aspiration of liquefied content helps to identify infective organism

• **Metastases**
- Usually seen in setting of widely disseminated metastatic disease
- Most common primary tumor is adenocarcinoma of lung
- Similar in appearance to soft tissue sarcoma, though metastases tend generally to be smaller than primary sarcoma

• **Lymphangioma**
- More common in subcutaneous tissues though often multicompartmental
- Thin-walled, multiloculated, septated mass
- Thick-walled with debris if complicated by infection or hemorrhage
- No grayscale flow movement (as in venous vascular malformation)
- No vascularity within septae

• **Intramuscular Extension of Baker Cyst**
- Occasionally extend into calf or distal thigh muscles
  - ± pericystic leakage or intracystic hemorrhage

• **Vascular Malformation**
- Determine whether low flow (common) or high flow (uncommon)
- Often multicompartment involvement
- Thin-walled, multiseptated with serpiginous cystic spaces ± phleboliths (characteristic)
- Variable hypo- or hyperechoic stromal component
- Slow venous flow may be seen only on grayscale as it is too slow to be detected by color Doppler imaging
- High probe pressure may efface and obscure vascular malformation
- MR imaging helpful to define full extent

• **Local Recurrence**
- Discrete rounded mass at site of primary tumor excision
- Need to differentiate from more linear, irregular hypoechoic scar tissue
- Ultrasound appearances of recurrence usually mimic those of primary tumor

• **Intramuscular Ganglion Cyst**
- Extension of ganglion cyst from joint into muscle.
- Similar ultrasound appearances to ganglion cyst elsewhere
- Hypoechoic ± echogenic "comet tail" artifacts
- ± intracystic hemorrhage or pericystic leakage
  - Pericystic leakage usually associated with pericystic inflammation

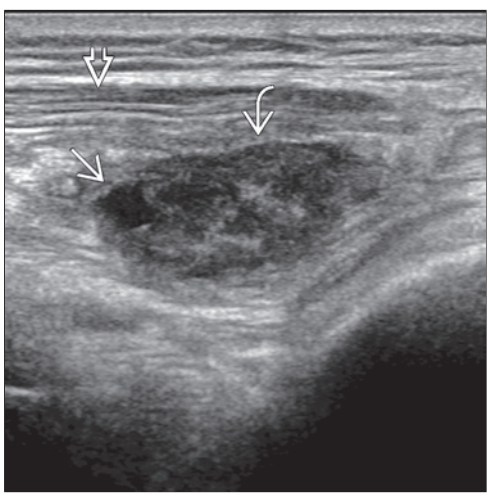
• **Granuloma**
- Much more common in subcutaneous tissues, especially gluteal region
- Usually following injection
  - Occasionally following trauma or foreign body implantation
- Majority have calcified rim

• **Diabetic Muscle Infarction**
- Occurs in diabetics with established vasculopathy
- Ill-defined hypoechoic area becoming better defined after 1 week
  - Muscle architecture remains vaguely detectable within hypoechoic area
  - No necrosis
  - No detectable vascularity at onset → mild to moderate hyperemia after about 1 week

Helpful Clues for Rare Diagnoses

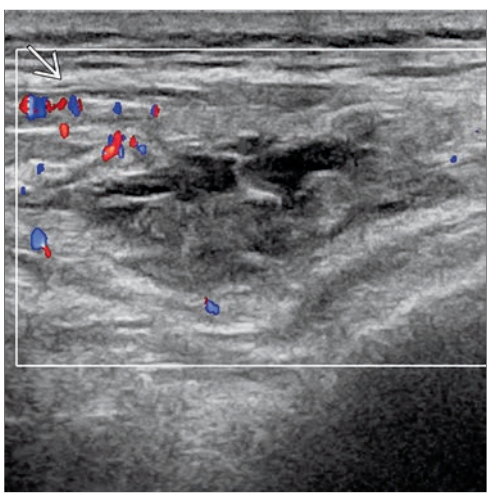
• **Parasitic Infection**
- Cysticercosis: Most common parasitic infection of soft tissue
  - Well-defined, small, hypoechoic mass with eccentric echogenic nidus representing scolex
  - Diagnosis can be confirmed by therapeutic response

Hematoma



Longitudinal ultrasound shows a slightly irregular buttock hematoma with some echo-poor cystic-like areas consistent with early liquefaction. There is moderate edema of the surrounding atrophic gluteal muscle.

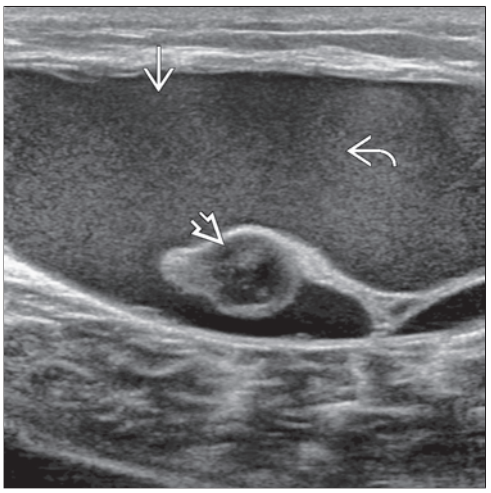
Hematoma



Longitudinal color Doppler ultrasound of the same hematoma as previous image shows typical mild hyperemia surrounding the hematoma.

HYPOECHOIC MUSCLE MASS

Hematoma

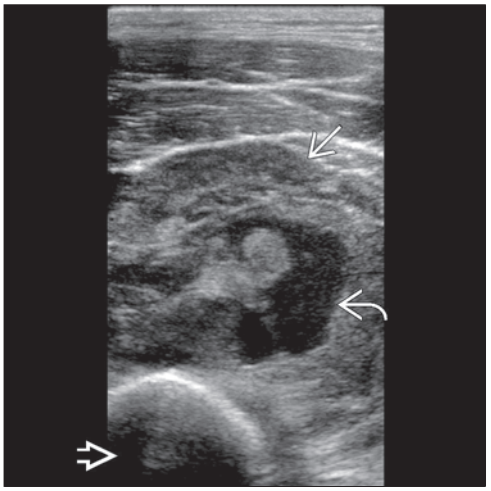


Muscle Tear

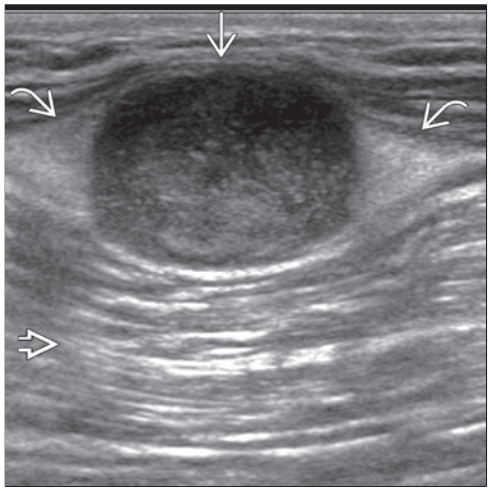


(Left) *Transverse ultrasound shows localized view of liquefied calf muscle hematoma following trauma 2 months earlier. Note the fine echogenic content suggestive of hemorrhage and the entrapped fluid. Aspiration to dryness yielded old blood.* ***(Right)*** *Longitudinal ultrasound shows a partially liquefied hematoma filling the gap formed by a myofascial tear between the medial belly of the gastrocnemius and the soleus muscles.*

Muscle Tear

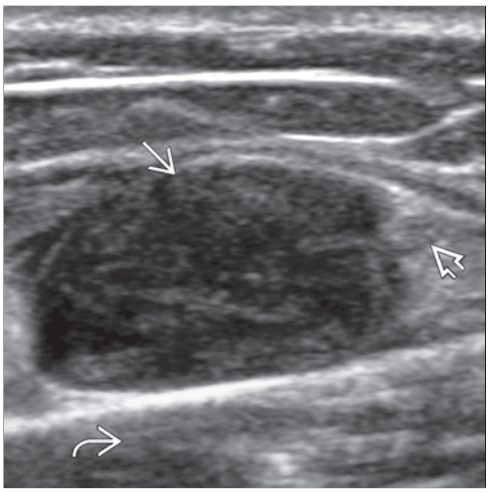


Nerve Sheath Tumor

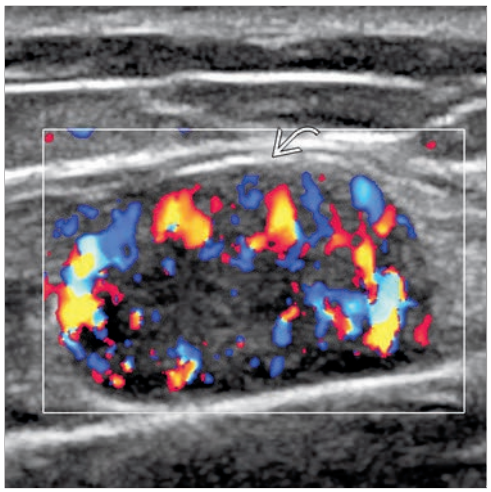


(Left) *Transverse ultrasound of a patient following a kick from a horse shows a large hypoechoic muscle tear within the disorganized, slightly swollen vastus lateralis muscle. The femoral shaft is normal.* ***(Right)*** *Longitudinal ultrasound shows a nerve sheath tumor within the sartorius muscle. The adjacent increased echogenicity is due to muscle fiber splaying leading to exaggeration of intramuscular fat ("split-fat" sign). There is characteristic mild acoustic enhancement.*

Nerve Sheath Tumor

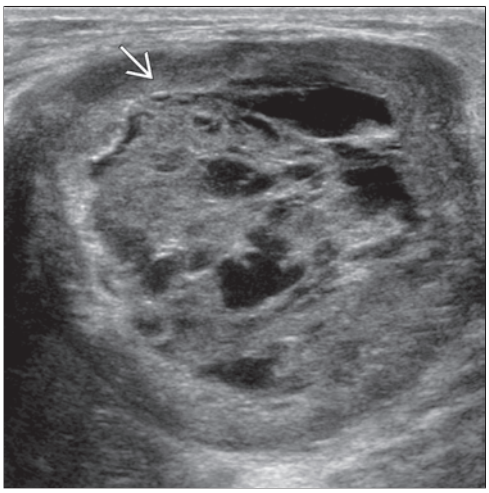


Nerve Sheath Tumor

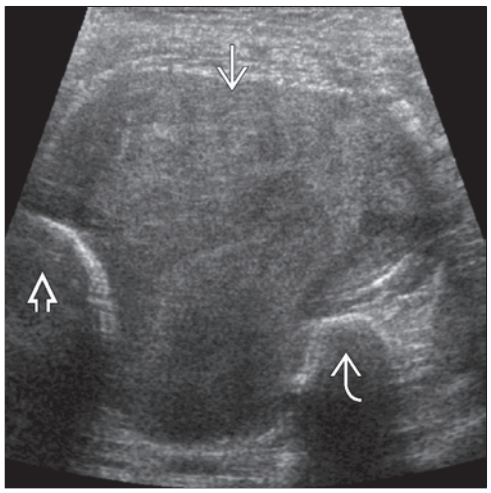


(Left) *Longitudinal ultrasound shows a nerve sheath tumor of the superficial peroneal nerve bulging into the peroneal musculature. The tumor is located eccentric to the nerve, which is located at the anterior aspect of the tumor. The fibula is normal.* ***(Right)*** *Longitudinal color Doppler ultrasound of the same nerve sheath tumor shows characteristic moderate hyperemia.*

Soft Tissue Sarcoma

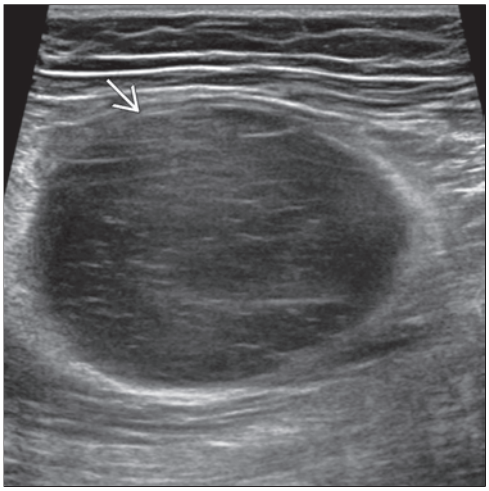


Soft Tissue Sarcoma

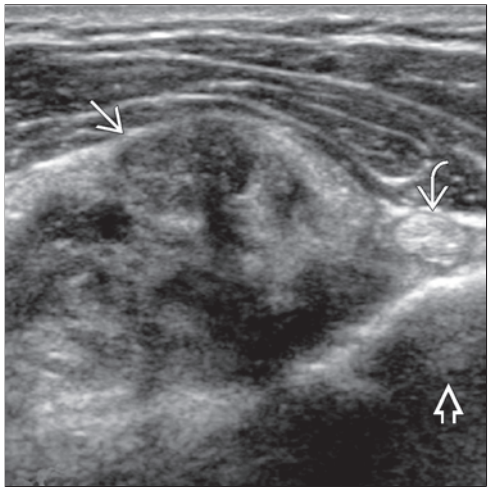


(Left) *Longitudinal ultrasound shows a large partially cystic hypoechoic mass within the medial head of the gastrocnemius. Mild intrinsic vascularity was present (not shown). Histology revealed a monophasic synovial sarcoma.* ***(Right)*** *Transverse ultrasound shows a large, well-defined alveolar soft part sarcoma bulging out anteriorly between the tibia and the fibula.*

Myxoma

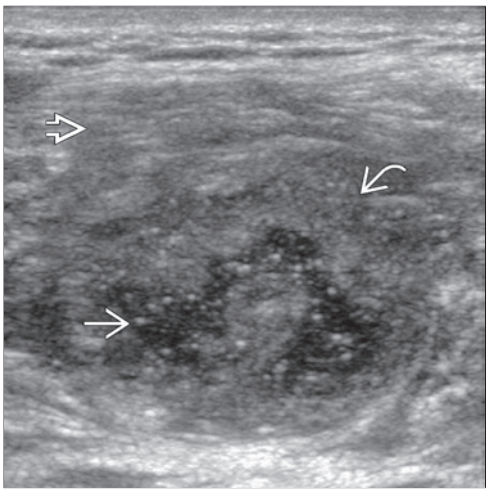


Fibromatosis

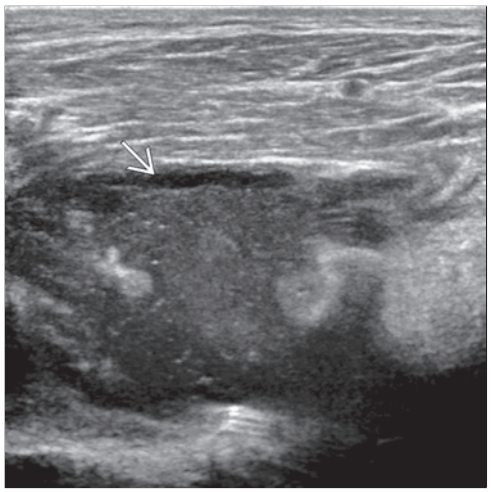


(Left) *Transverse ultrasound shows a large intramuscular myxomatous-type mass in the midthigh region. This may represent either a myxoid-type "ancient" schwannoma or a myxoma. Histology confirmed the latter diagnosis.* ***(Right)*** *Transverse ultrasound shows a well-defined heterogeneous mass alongside the coracoid process. Biopsy confirmed fibromatosis. The long head of biceps tendon is normal.*

Abscess



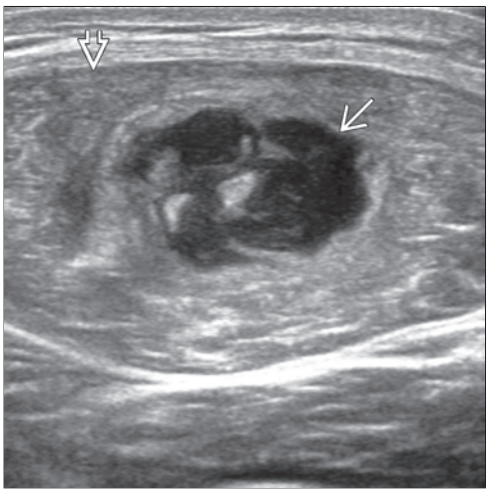
Abscess



(Left) *Longitudinal ultrasound shows an intramuscular abscess. Many small echogenic foci due to proteinaceous aggregates or gas are present and seen to move on real-time imaging. The margin is ill-defined with moderate edema of the surrounding muscle.* ***(Right)*** *Longitudinal ultrasound shows a large irregular fluid collection present on the posteromedial aspect of the distal femur. Aspiration yielded purulent fluid that grew Staphylococcus aureus.*

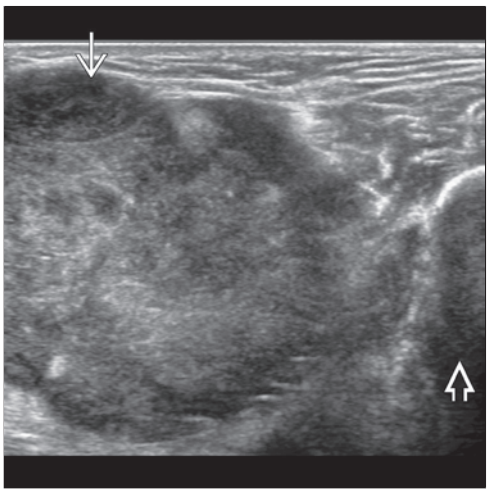
HYPOECHOIC MUSCLE MASS

Abscess

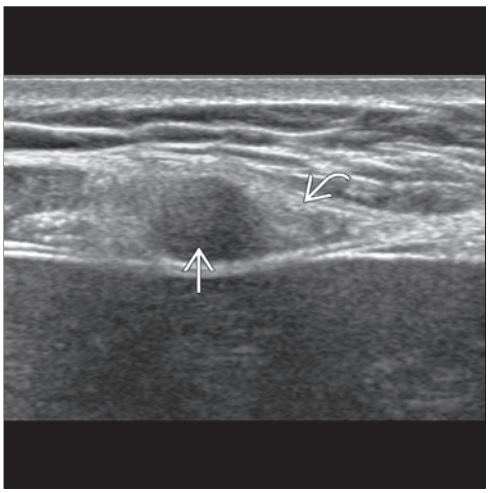


(Left) *Transverse ultrasound in a patient with acute myeloid leukemia, pancytopenia, and fever shows a medium-sized abscess present within a moderately edematous rectus femoris muscle. Aspiration yielded Pseudomonas aeruginosa.* ***(Right)*** *Transverse ultrasound shows a large mildly heterogeneous metastatic tumor from carcinoma of the lung within the brachialis muscle of the arm. Mild intratumoral vascularity was present (not shown). The humerus is normal.*

Metastases

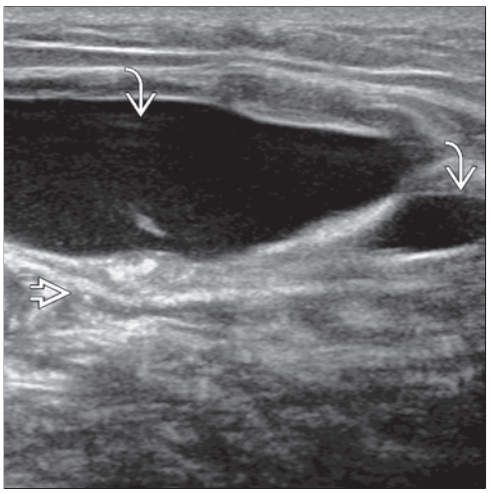


Metastases

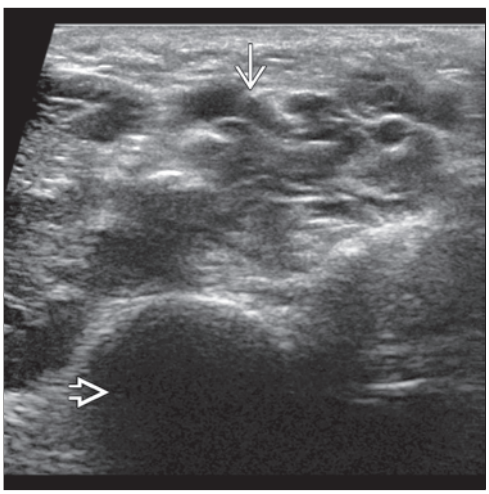


(Left) *Transverse ultrasound in an HIV/AIDS patient with known EBV-related liver and adrenal tumors shows a small hypoechoic rectus abdominus muscle tumor with moderate surrounding edema compatible with an intramuscular metastatic deposit.* ***(Right)*** *Longitudinal oblique ultrasound shows the distal end of a large Baker cyst that has ruptured into the medial belly of the gastrocnemius muscle. This rupture is not acute as shown by the poor wall definition and lack of edema.*

Intramuscular Extension of Baker Cyst

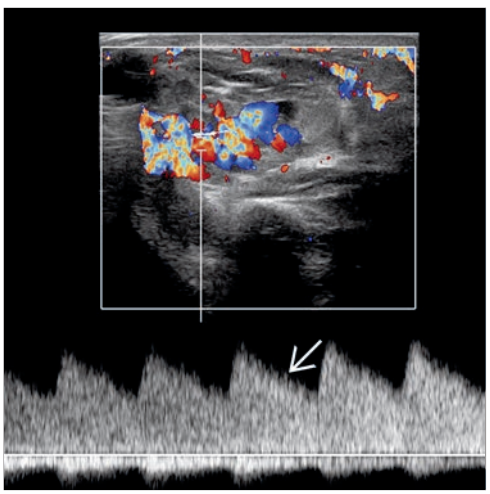


Vascular Malformation

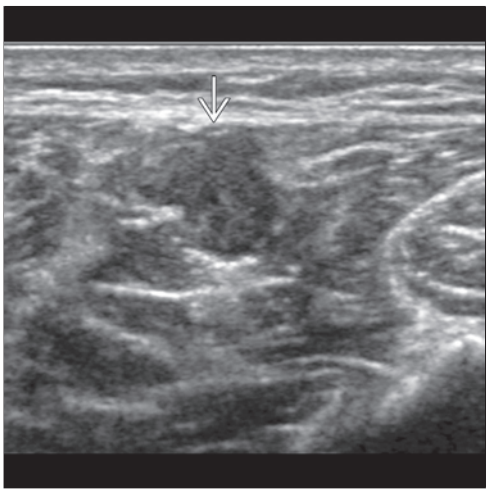


(Left) *Transverse ultrasound shows a vascular malformation with large serpiginous vascular channels occupying all of the hypothenar muscle. The 1st metacarpal bone is normal.* ***(Right)*** *Transverse spectral and color Doppler ultrasound of the same lesion shows the vascular malformation to be a moderate- to high-flow lesion with low-resistance arterial intralesional flow.*

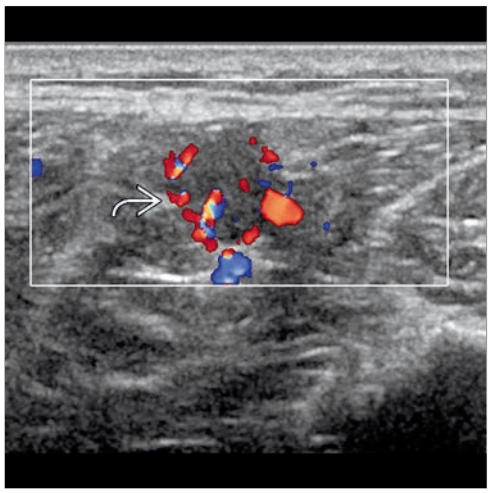
Vascular Malformation



Local Recurrence

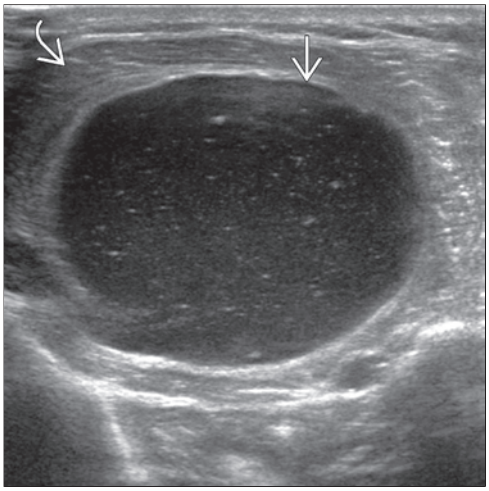


Local Recurrence

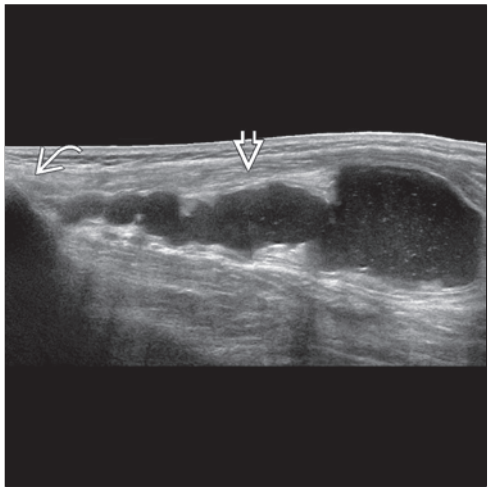


(Left) *Transverse ultrasound of a patient with resection of a soleus muscle inflammatory myxohyaline tumor 18 months earlier shows a small hypoechoic intramuscular nodule. Ultrasound-guided biopsy confirmed local tumor recurrence.* ***(Right)*** *Transverse color Doppler of the same tumor shows moderate marginal hyperemia.*

Intramuscular Ganglion Cyst

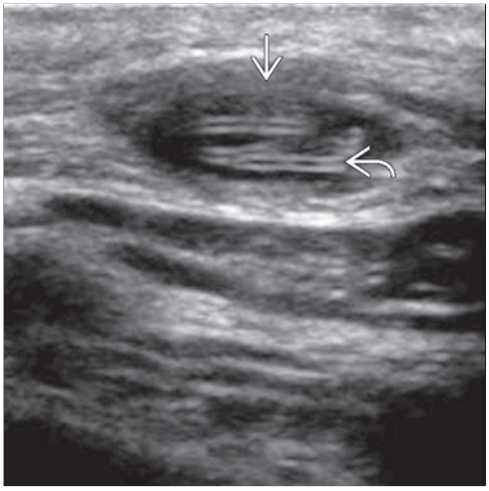


Intramuscular Ganglion Cyst

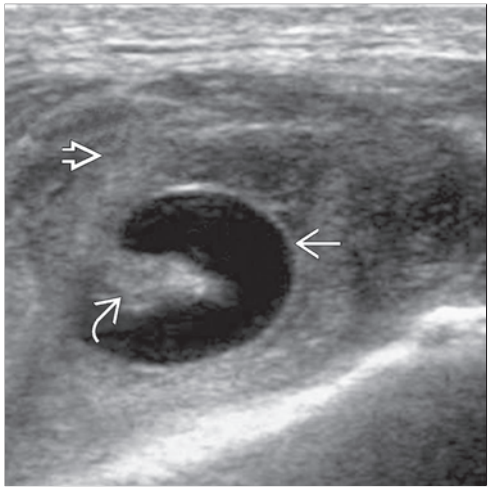


(Left) *Transverse ultrasound shows a hypoechoic cystic-type mass with small echogenic foci within the tibialis anterior muscle.* ***(Right)*** *Longitudinal ultrasound of the same tumor shows a wide hypoechoic tract connecting the proximal end of the cyst to the prominal tibiofibular joint. This represents a paraarticular ganglion cyst that has extended into the tibialis anterior muscle.*

Parasitic Infection



Parasitic Infection



(Left) *Longitudinal ultrasound of the hand shows cysticercosis infestation of the thenar muscle with a hypoechoic cyst containing an echogenic tapeworm. (Courtesy V. Hardas, MD.)* ***(Right)*** *Transverse ultrasound shows intramuscular cysticercosis infestation as a small, hypoechoic intramuscular mass with an eccentric echogenic nidus representing the scolex. The surrounding arm musculature is edematous. (Courtesy V. Hardas, MD.)*

HYPERECHOIC MUSCLE MASS

DIFFERENTIAL DIAGNOSIS

Common
- Intermuscular Lipoma
- Intramuscular Lipoma
- Muscle Edema
- Vascular Malformation
- Hematoma

Less Common
- Foreign Body
- Soft Tissue Sarcoma
- Muscle Metastases
- Local Recurrence
- Peripheral Nerve Sheath Tumor
- Myositis
- Rhabdomyolysis
- Venous Dilatation

ESSENTIAL INFORMATION

Key Differential Diagnosis Issues
- Often need low-frequency transducer to visualize full depth of muscle
- Muscle echogenicity varies according to orientation of muscle fiber and transducer, and relative amount of lean or fatty tissue
  - Lean muscle tends to be more hypoechoic
  - More fatty muscle (fatty atrophy) tends to be more hyperechoic
- As their muscle fibers are aligned in different directions, anisotropy can be used to identify different muscles
- Scanning along muscle length in transverse plane indicates whether mass is present and delineates its boundaries
- Dynamic scanning is not as helpful for muscle as it is for tendons, nerves, and joints
  - Muscle may be hyperechoic when edematous
  - MR is more sensitive than ultrasound at depicting muscle edema

Helpful Clues for Common Diagnoses
- **Intermuscular Lipoma**
  - Located deep to investing fascia
  - May be classified as subfascial, intermuscular, intramuscular, or submuscular in location
    - Subfascial: Between investing fascia and muscle
    - Intermuscular: Between muscles (most common)
    - Intramuscular: Within muscle
    - Submuscular: Beneath muscle (i.e., juxtacortical); least common location
  - Ultrasound appearances of deep lipomas are similar to subcutaneous lipomas but more variable
    - Usually larger than subcutaneous lipomas at presentation
    - Less compressible
    - Occasional vessels detected as opposed to subcutaneous lipoma, which are nearly always avascular
  - Discrete noninfiltrative mass with well-defined convex margins
  - Fusiform or oblong in shape with long axis parallel to skin
  - May be hypoechoic (infrequent)
    - Usually hyperechoic to muscle
  - Fine linear echogenic striations running parallel to long axis of tumor in both transverse and longitudinal planes
  - May show acoustic enhancement, as ultrasound transmission in fat > muscle
  - No vascularity in or around lipoma on color Doppler
    - Occasionally, several vessels traversing lipoma may be visible
  - Consider malignancy if following features are present
    - Large mass
    - Thick (> 2 mm) septations
    - Nodular areas of nonlipomatous tissue
    - Cyst-like or necrotic areas within tumor
    - Majority of tumor is nonlipomatous
  - 4 distinct histological types of liposarcoma
    - Well-differentiated liposarcoma
    - Myxoid liposarcoma
    - Pleomorphic liposarcoma
    - Dedifferentiated liposarcoma
  - MR is helpful for surgical planning and establishing a baseline for all deep-seated lipomas
- **Muscle Edema**
  - From inflammation, infection, venous congestion, trauma
  - Muscle becomes hyperechoic; intense edema is hypoechoic
  - Variable hyperemia
  - Usually has associated subcutaneous ± perifascial edema
  - Diffuse intramuscular bleeding can give a similar appearance
- **Vascular Malformation**
  - Vascular malformation and hemangioma indistinguishable on ultrasound appearances
  - Hemangioma
    - Vascular tumor of childhood: Progressive → regressive stages
    - Regresses by puberty
    - Any vascular mass present in adulthood is a vascular malformation and not a hemangioma
  - Vascular malformation
    - Vascular dysmorphogenesis
    - Enlarges in line with skeletal development
    - Changes shape in adulthood due to thrombosis and revascularization
  - 5 different types of vascular malformation depending on predominant vascular feature
    - Capillary, venous, arteriovenous, lymphatic, or mixed
  - Ultrasound is extremely helpful in establishing diagnosis and assessing flow and relative amount of stroma vs. vascular component including
    - Whether high flow or low flow
    - Relative percentage of visible vascular channels vs. echogenic stroma component within lesion; echogenic stroma component often contains vascular channels too small to be resolved with ultrasound
    - MR better at assessing lesion extent and multiplicity
- **Hematoma**
  - Intramuscular hematoma may occur due to trauma, anticoagulation, vascular malformation, or sarcoma
    - Anterior thigh is common site as it is prone to muscle contusion injury
  - Acute hematoma is usually isoechoic or hyperechoic to muscle

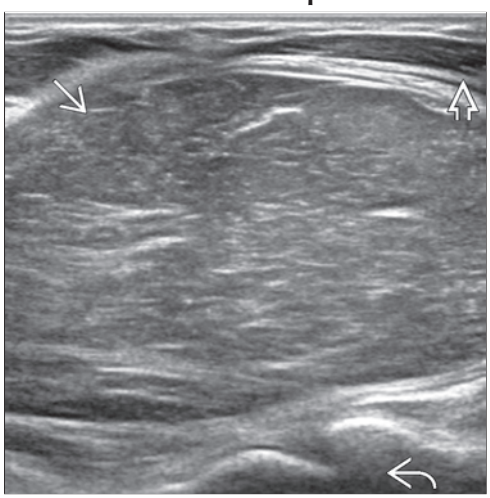
- ± layering due to repeated hemorrhage
- Becomes more hypoechoic with increasing liquefaction after several days
- ± sedimentation present after a few minutes of rest

- Mild diffuse intramuscular hemorrhage may be overlooked on ultrasound, as ill-defined hyperechoic areas blend with muscle
  - MR is more sensitive than ultrasound at detecting mild muscle injury
- Remember that intramuscular sarcomas or vascular malformations may bleed spontaneously or during exercise
  - If no trauma history, always consider likelihood of underlying precipitating condition

Helpful Clues for Less Common Diagnoses

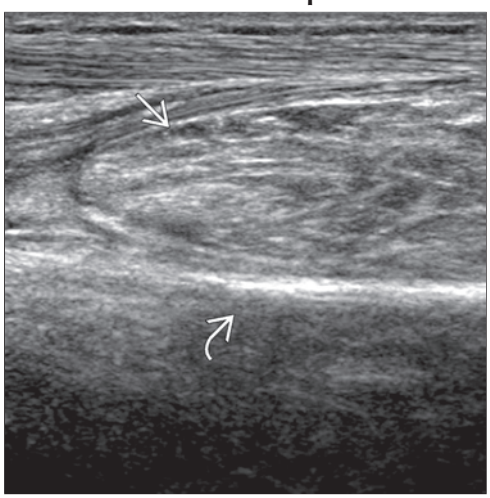
- **Foreign Body**
  - Lodges in subcutaneous tissues much more commonly than muscle
  - Nearly all foreign bodies are echogenic
  - ± reverberation artifact or acoustic shadowing
  - Bamboo and noncompact wood are difficult to see because they absorb fluid and have echogenicity similar to soft tissue
    - Always repeat ultrasound after 1-3 days if foreign body is not detected initially
  - Missed foreign bodies often develop hypoechoic rim
    - This rim is composed of hyperemic granulation and fibrous tissue
    - Makes foreign body more conspicuous
- **Soft Tissue Sarcoma**
  - Occur most frequently in muscle layer
    - Majority are hypoechoic
    - Occasionally hyperechoic due to fat, fibrosis, or hemorrhage
    - Ultrasound appearances do not conform to recognized tumor (e.g., nerve sheath tumor, lipoma, vascular malformation, fibromatosis, etc.)
    - If suspected, usually requires percutaneous biopsy
- **Muscle Metastases**
  - Most patients have known primary tumor with disseminated metastases
  - Adenocarcinoma > squamous cell carcinoma
  - Breast, lung, and upper aerodigestive tract are common primary sites
  - Ill-defined, hypoechoic muscle mass aligned along long axis of muscle (typical)
    - Ultrasound appearances similar to those of primary tumor
  - Often several muscle metastases occur within same area
  - Percutaneous biopsy is diagnostic and indicated if confirmation required
- **Local Recurrence**
  - Discrete mass at site of primary tumor excision
  - Ultrasound appearances are similar to those of primary tumor
- **Peripheral Nerve Sheath Tumor**
  - Majority of peripheral nerve sheath tumors are hypoechoic
    - Similar appearance to subcutaneous nerve sheath tumor
    - Tumoral hyperechogenicity indicates internal hemorrhage
- **Myositis**
  - Ill-defined increase in muscle echogenicity and swelling of muscle, decreased definition of muscle architecture ± focal hyperemia
    - Inflammatory myositis is often symmetrical
  - MR is more sensitive than ultrasound at detecting mild myositis
- **Rhabdomyolysis**
  - Necrosis of skeletal muscle
    - Contents of injured muscle cells leak into circulation
    - If severe → electrolyte imbalance, acidosis, coagulopathy, hypovolemia, and acute renal failure
  - Many causes, including trauma, strenuous muscle exercise, and prolonged muscle compression
  - Diffusely echogenic muscle or muscles
- **Venous Dilatation**
  - Slow-moving blood → red cell clumping → vascular hyperechogenicity
    - Sedimentation effect may be visible if vein at rest

Intermuscular Lipoma



Longitudinal ultrasound shows a large lipoma on the lateral aspect of the elbow and deep to the brachioradialis muscle. Note the fine linear striations present throughout the tumor typical of lipoma.

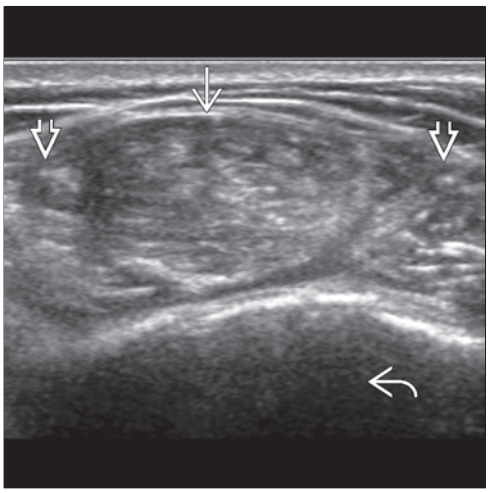
Intramuscular Lipoma



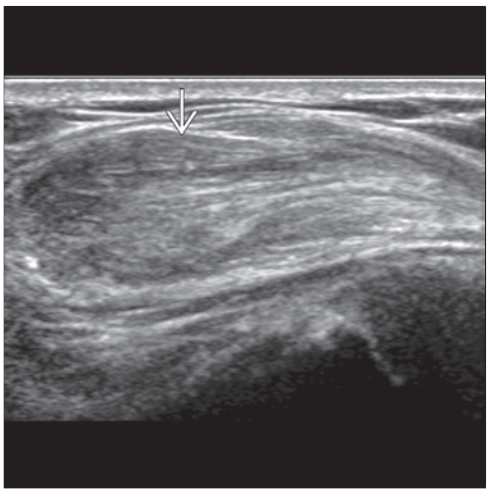
Longitudinal ultrasound shows an intramuscular lipoma on surface of fibula within the peroneal brevis muscle. The tumor is slightly more heterogeneous than a subcutaneous lipoma, though otherwise very similar.

HYPERECHOIC MUSCLE MASS

Intramuscular Lipoma

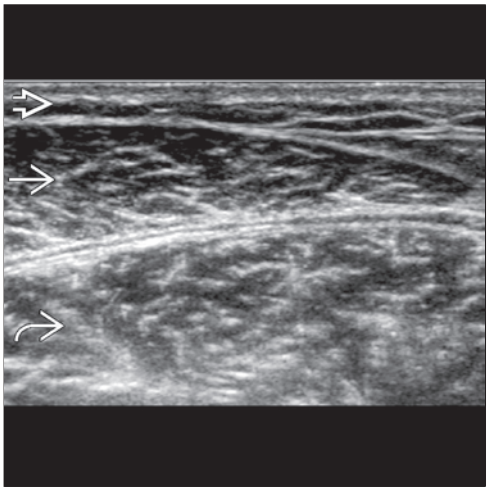


Intramuscular Lipoma

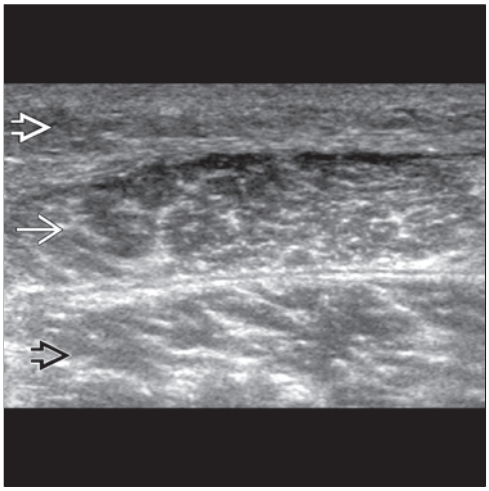


(Left) *Transverse ultrasound shows a medium-sized intramuscular lipoma within the midportion of the deltoid muscle. The deltoid is a common site for intramuscular lipoma. The humeral head is normal.* ***(Right)*** *Longitudinal ultrasound of the same tumor shows the typical mild hyperechogenicity and fine linear striations of a lipoma. There are no untoward features present. There is no need for percutaneous biopsy in this case.*

Muscle Edema

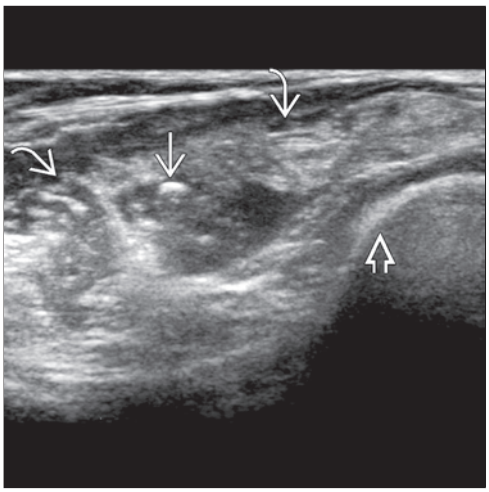


Muscle Edema

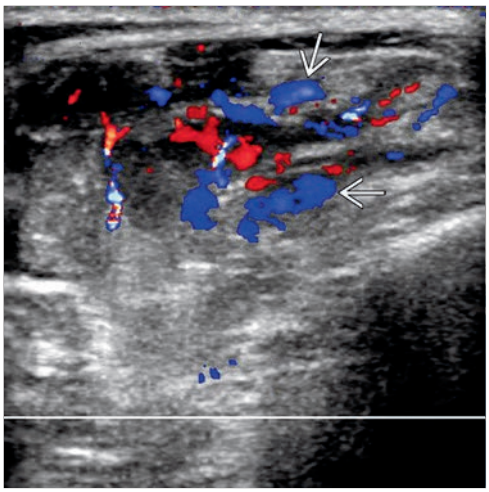


(Left) *Transverse ultrasound shows a normal contralateral limb for comparison. The normal hypoechogenicity and appearance of the gastrocnemius and soleus muscles, as well as subcutaneous fat, can be appreciated.* ***(Right)*** *Longitudinal ultrasound shows moderate edema of the subcutaneous tissues as well as the gastrocnemius and soleus muscles of the calf. Edematous muscle is diffusely hyperechoic with preservation of muscle architecture.*

Vascular Malformation



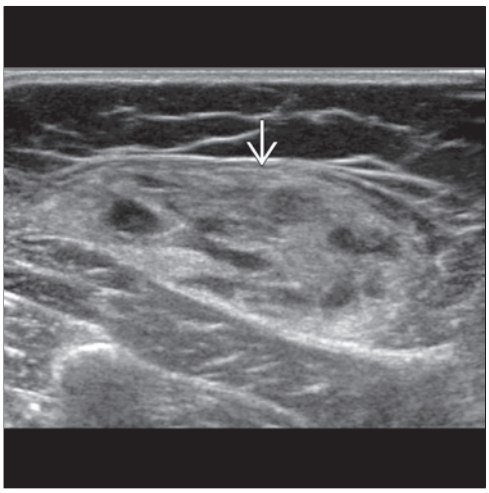
Vascular Malformation



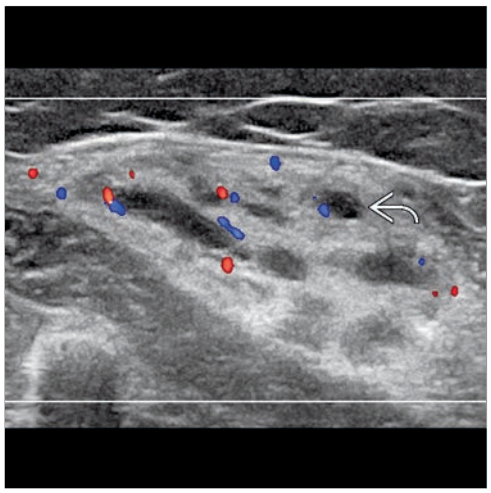
(Left) *Transverse ultrasound shows a moderately sized, hyperechoic vascular malformation within the distal part of the triceps alongside the olecranon. The vascular malformation is primarily composed of large vessels. A single phlebolith is present.* ***(Right)*** *Correlative transverse color Doppler ultrasound in the same patient shows slow-flowing vascular channels occupying most of the lesion. The findings are consistent with a venous vascular malformation.*

HYPERECHOIC MUSCLE MASS

Vascular Malformation

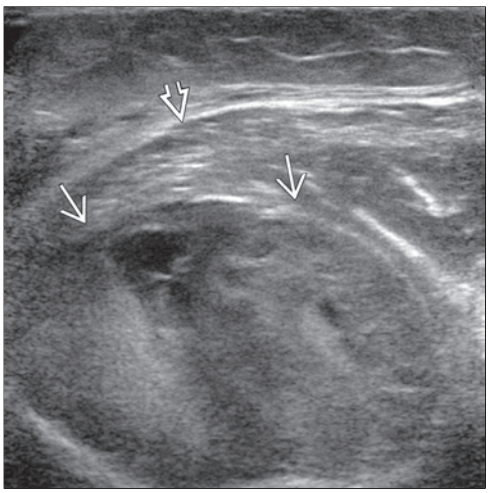


Vascular Malformation

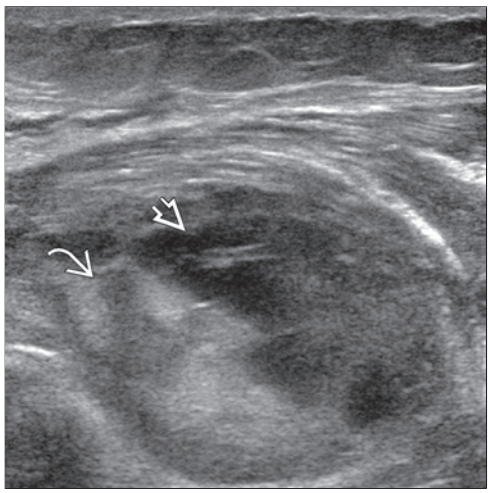


(Left) *Longitudinal ultrasound shows a medium-sized, well-defined intramuscular vascular malformation within the gastrocnemius muscle. The vascular malformation is composed of about 25% venous-type channels with about 75% echogenic stroma component. No phleboliths are present.* ***(Right)*** *Longitudinal color Doppler ultrasound shows the vascular malformation to be low flow with mild hyperemia. Venous channels often have no demonstrable color flow due to slow flow.*

Hematoma

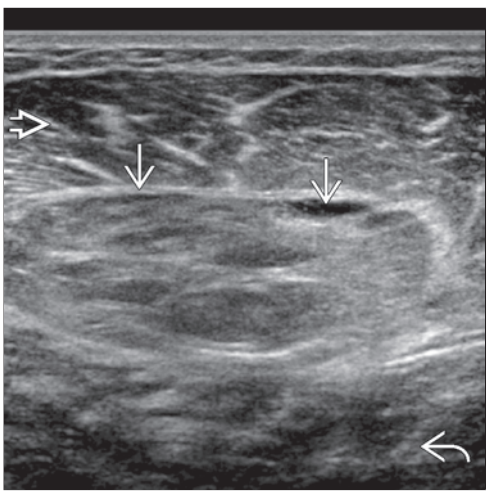


Hematoma

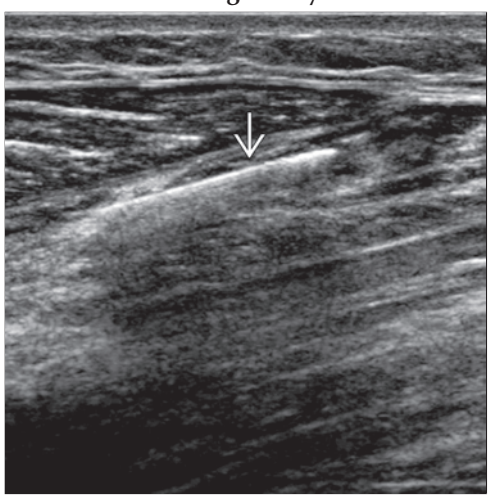


(Left) *Transverse ultrasound of an anticoagulated patient shows an acute hyperechoic hematoma within the vastus lateralis muscle .* ***(Right)*** *Transverse ultrasound of the same hematoma after 5 minutes of rest shows sedimentation of content with hypoechogenicity of the more superficial component and hyperechogenicity of the deeper component . Sedimentation is an absolute indicator of fluid content.*

Hematoma



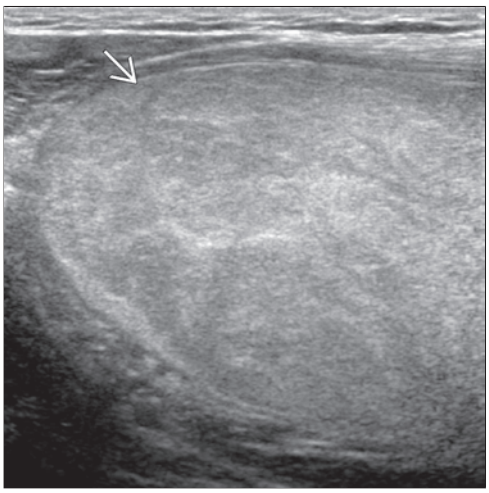
Foreign Body



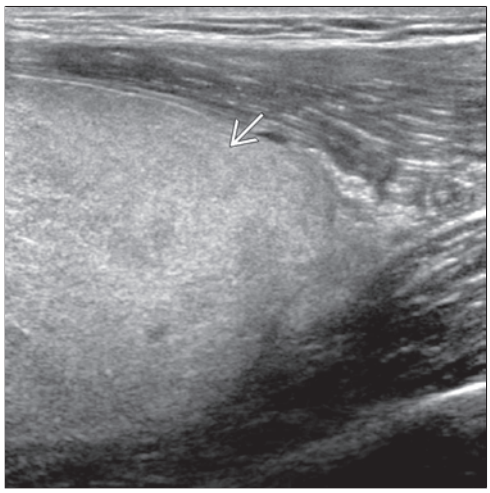
(Left) *Transverse ultrasound shows a largely hyperechoic, well-defined hematoma at the myofascial junction between the gastrocnemius and soleus muscles. There is some early sedimentation superficially .* ***(Right)*** *Longitudinal US shows a retained needle in the calf muscle, which had been present for many years. During US-guided removal with forceps, the needle was found to be firmly adherent to the adjacent muscle and had to be pried off by rotating the forceps.*

HYPERECHOIC MUSCLE MASS

Soft Tissue Sarcoma

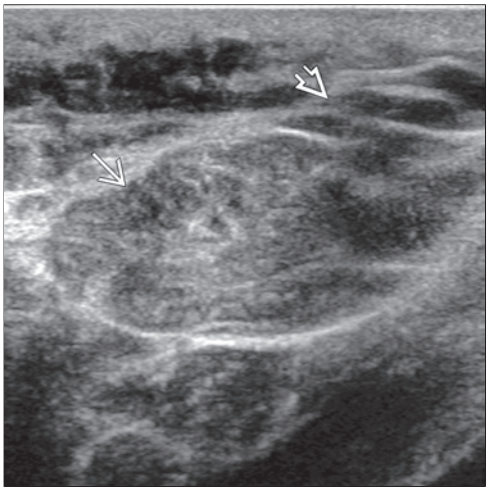


Soft Tissue Sarcoma

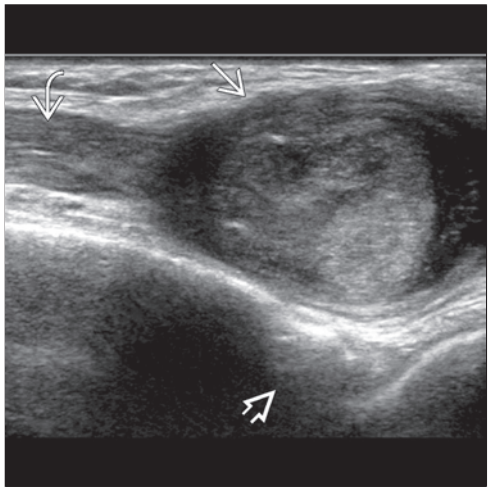


(Left) *Longitudinal ultrasound shows a large hyperechoic tumor ➔ within the calf musculature. Ultrasound-guided biopsy for histology revealed a liposarcoma.* ***(Right)*** *Longitudinal ultrasound shows the more distal end of the same tumor ➔. Color Doppler ultrasound (not shown) showed only minimal tumor vascularity.*

Muscle Metastases

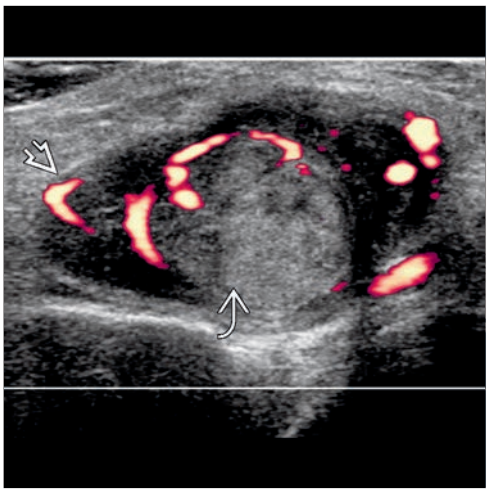


Peripheral Nerve Sheath Tumor

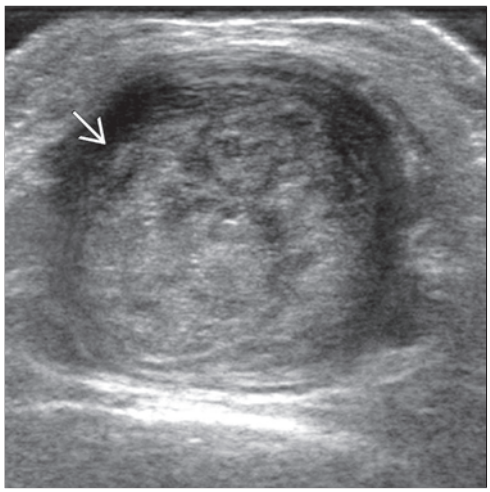


(Left) *Transverse ultrasound shows a large echogenic metastasis ➔ within the teres major muscle ➔. This patient had disseminated shoulder metastases from a nasopharyngeal primary tumor.* ***(Right)*** *Longitudinal ultrasound shows a moderately hyperechoic nerve sheath tumor ➔ of the deep peroneal nerve anterior to the ankle joint ➔. Hyperechogenicity within a nerve sheath tumor usually indicates intratumoral hemorrhage. The deep peroneal nerve is very thickened ➔ proximally.*

Peripheral Nerve Sheath Tumor



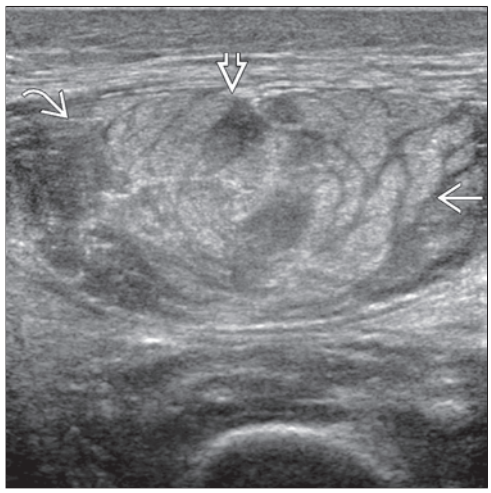
Peripheral Nerve Sheath Tumor



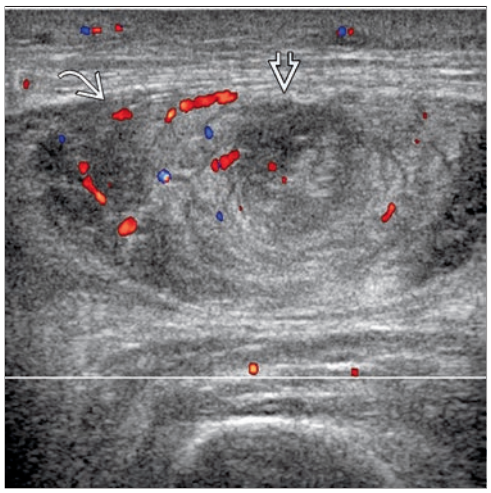
(Left) *Longitudinal power Doppler ultrasound of the same tumor as previous image shows more peripheral hyperemia ➔. Note how the central hyperechoic hemorrhagic area ➔ is not hyperemic.* ***(Right)*** *Transverse ultrasound shows an echogenic nerve sheath tumor ➔ of a small intramuscular nerve in the calf. This histology-confirmed nerve sheath tumor had recently increased in size, most likely due to intratumoral hemorrhage. Intratumoral hemorrhage is not a sign of malignancy.*

HYPERECHOIC MUSCLE MASS

Myositis

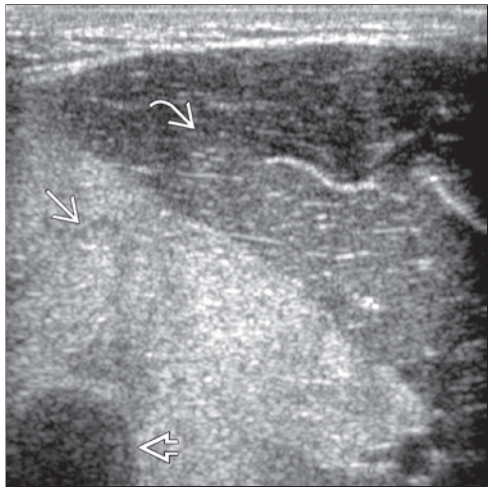


Myositis

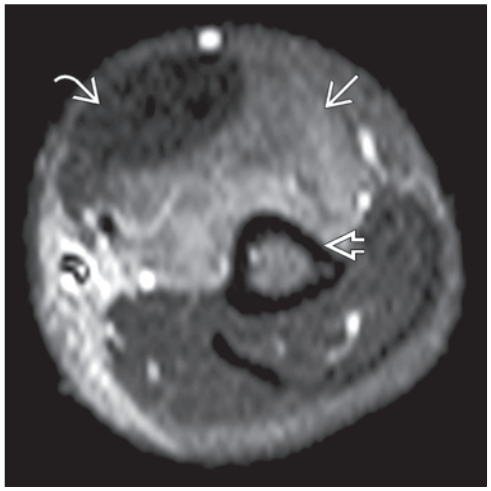


(Left) *Transverse ultrasound shows diffuse edema and swelling of the rectus femoris muscle. The linear muscle striations are still preserved with some more edematous hypoechoic areas. Similar changes affected the vastus medialis and lateralis muscles as well as the contralateral thigh.* ***(Right)*** *Transverse color Doppler ultrasound of the same muscle shows moderate hyperemia. The hypoechoic edematous area is not hyperemic. The overall appearances indicate an inflammatory myositis.*

Rhabdomyolysis

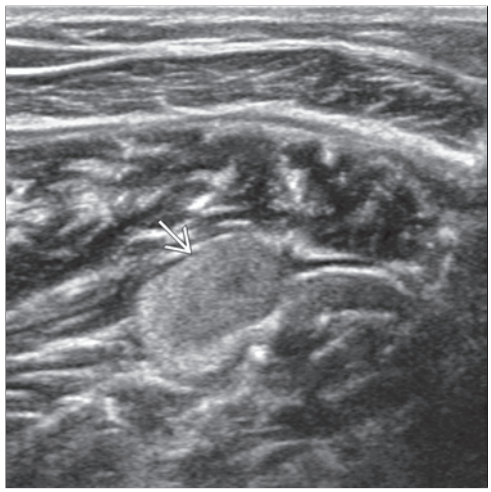


Rhabdomyolysis

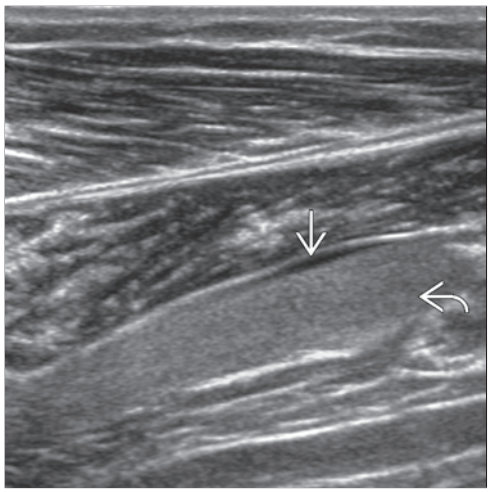


(Left) *Transverse US shows a hyperechoic brachialis muscle following unaccustomed exertion on a rowing machine, indicative of delayed-onset muscle soreness with rhabdomyolysis. The biceps brachii muscle is normal. Note the humeral shaft.* ***(Right)*** *Correlative axial T2WI MR with fat suppression in the same location shows the edematous brachialis muscle with a normal biceps brachii muscle. Note the humeral shaft.*

Venous Dilatation



Venous Dilatation



(Left) *Transverse ultrasound shows a rounded echogenic structure within the soleus muscle.* ***(Right)*** *Longitudinal ultrasound of same patient shows that this echogenic structure is a dilated deep vein with slow flow. The echogenic content is caused by clumping of slow-moving red blood cells. These intravascular red cell aggregates show early sedimentation superficially.*

CYSTIC SOFT TISSUE MASS

DIFFERENTIAL DIAGNOSIS

Common
- Ganglion Cyst
- Bursal Distension

Less Common
- Abscess
- Hematoma
- Seroma
- Dermoid/Implantation Dermoid
- Epidermoid Cyst
- Parameniscal Cyst
- Metastasis
- Vascular Malformation
- Lymphatic Malformation
- Fat Necrosis
- Schwannoma
- Myxoma
- Sarcoma
- Lymph Node
- Venous Varix
- Aneurysm
- Pseudoaneurysm

ESSENTIAL INFORMATION

Key Differential Diagnosis Issues
- Adjust gain setting to optimize visualization of internal contents
  - Cystic-type mass is not necessarily anechoic
  - Many cystic lesions contain hyperechoic fluid or echogenic foci
- All cystic-type masses should be evaluated with color Doppler imaging
  - May reveal internal vascularity in hypoechoic lesion initially considered to be cystic
  - May reveal previously unrecognized vascular structures alongside cystic-type mass

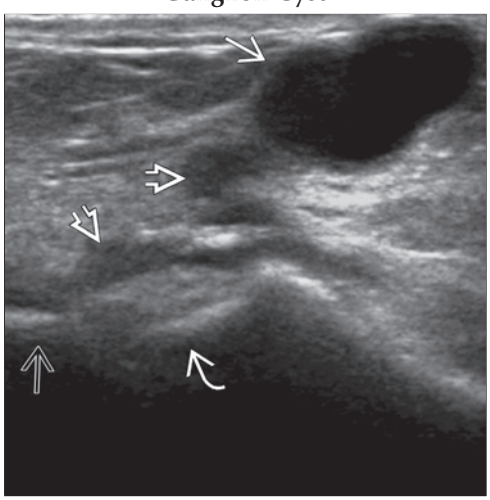
Helpful Clues for Common Diagnoses
- **Ganglion Cyst**
  - Most common cystic-type mass
  - Filled with gelatinous material of variable viscosity
  - Occurs alongside joints
  - Synovial fluid squeezed out from joint through capsular defect
  - Usually can see cyst point toward nearby joint
  - Increase in extent through process of cyst enlargement → rupture → consolidation
    - Some can be extensive, serpiginous, multiloculated, and quite removed from joint of origin
    - May extend into muscle and simulate myxoma
  - Fluid-filled mass with stalk extending toward joint
  - Ovoid or irregular configuration with stalk connecting to joint of origin
  - No hyperemia except with recent leakage when surrounding tissues may be mildly hyperemic and edematous due to pericystic inflammation
  - Communication with joint is not always apparent
  - Locate tell-tale stalk of cyst and trace it towards joint of origin
- **Bursal Distension**
  - Inflammation of lining of bursae
  - Synovial bursae: Constant synovial-lined bursae which occur in defined anatomical locations
  - Adventitial bursae: Nonsynovial-lined bursae that are acquired due to friction between opposing parts
  - Synovial-lined space is not visualized on ultrasound unless distended with fluid
  - Most bursae are accessible to ultrasound
  - Ultrasound facilitates image-guided aspiration or injection
  - Bursitis is common, but infective bursitis is uncommon
  - Chronic bursitis is often associated with wall-thickening and internal debris
  - Baker cyst = distended semimembranous, gastrocnemius bursa

Helpful Clues for Less Common Diagnoses
- **Abscess**
  - Usually in immunosuppressed or at-risk patient
  - Majority are hypoechoic; some are hyperechoic if contents are viscous
    - Look for moving echoes within lesion on real-time imaging
    - Surrounding edema or inflammation
    - Peripheral hyperemia
  - Posterior enhancement is characteristic
  - Echo movement on real-time imaging
- **Hematoma**
  - All hematomas start to visibly liquefy after about 1 week
    - Some proceed to margination with complete liquefaction
    - Others proceed to gradually reduce in size without margination and liquefaction
    - ± calcification (uncommon)
- **Seroma**
  - Only occurs following tissue disruption due to surgery or trauma
  - No signs or symptoms of infection
  - Do not occur spontaneously
  - Fluid collection usually deep to investing fascia
    - ± septations
- **Dermoid/Implantation Dermoid**
  - Implantation of epidermal fragments into subdermal tissues by penetrating injury
  - Epidermis continues to grow and forms cyst lined with stratified squamous epithelium and filled with keratin
- **Epidermoid Cyst**
  - Most are heterogeneous and mildly hyperechoic
  - Linear, hyper-reflective, disc-like areas represent layered keratin aggregates ± cholesterol deposition
  - Cleft-like or filiform anechoic or hypoechoic areas are due to cyst-like spaces lacking keratin
- **Parameniscal Cyst**
  - Fluid squeezed from peripheral part of meniscus
  - Usually well-defined and filled with hypoechoic gelatinous-type fluid
  - Normally associated with meniscal tear
    - Nearly always horizontal tear
  - Meniscal tear may not be seen occasionally
- **Metastasis**
  - Metastasis can be cystic or necrotic
- **Vascular Malformation**
  - Proliferative
    - Hemangioma: Proliferation → stabilization → involution

- Kaposiform hemangioendothelioma, Kaposi sarcoma, and angiosarcoma
- Static
  - Arterial, venous, capillary, lymphatic, or mixed depending on predominant vascular pattern
  - Best assessed with color and pulsed Doppler ultrasound
  - Do not proliferate but change shape due to thrombosis, hemorrhage, or infection
  - Microvascular component looks like supporting stroma on imaging because microvessels cannot be resolved
- Each type of vascular malformation may also
  - Be focal or diffuse
  - Possess ectatic vessels
  - Have variable microvascular component

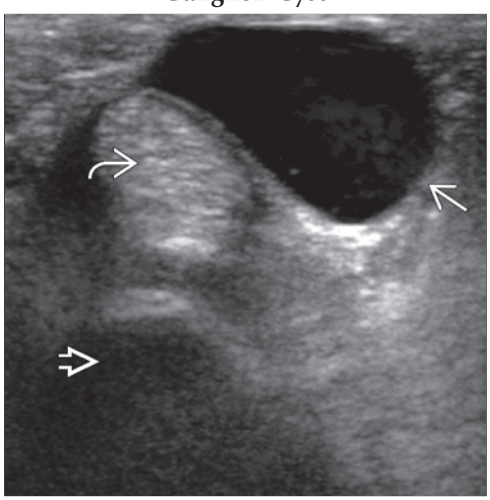
- **Lymphatic Malformation**
  - Unilocular/multilocular
  - Anechoic compressible cysts with thin walls and intervening septa
  - No vascularity demonstrated
- **Fat Necrosis**
  - Fat trauma → fat inflammation → fat necrosis → liquefaction
    - Visible liquefaction occurs with large areas of fat necrosis
  - ± calcification due to fatty acids combining with calcium to form calcium soap
- **Schwannoma**
  - Majority of peripheral schwannomas have a small amount (≤ 10%) of myxoid tissue or fluid component
    - Minority of peripheral schwannomas have a larger (> 30%) myxoid tissue or fluid component
    - Cystic component may be due to necrosis, hemorrhage, or fluid accumulation due to altered tumor barrier
  - Cystic schwannoma tends to be larger and more compressive with shorter duration of neurological symptoms
  - Nerve often shows slight enlargement just proximal and distal to tumor
- **Myxoma**
  - Occurs in muscle
  - Well-defined, roundish hypoechoic mass ± surrounding muscle compression or atrophy
    - ± echogenic colloid aggregates in tumor matrix
- **Sarcoma**
  - Appear cystic if fluid, hemorrhagic, necrotic, or myxoid component
    - Myxoid tumors include liposarcoma, malignant peripheral nerve sheath tumor, and malignant fibrous histiocytoma
- **Lymph Node**
  - Cystic nodes are most commonly due to tumor necrosis or tuberculosis
  - Lymphoma nodes may also appear cystic
- **Venous Varix**
  - Focal dilatation of vein
- **Aneurysm**
  - Popliteal aneurysm is most common appendicular aneurysm
    - Associated with older age, male gender, and atherosclerosis
    - ~ 50% bilateral
  - Most other appendicular aneurysms are associated with vasculopathy, such as polyarthritis nodosa or arterial malformation
- **Pseudoaneurysm**
  - Associated with trauma, vascular surgery, or impingement from pedunculated osteochondroma
  - Usually hypoechoic or anechoic structure
  - Thrombus may be seen in lumen
  - Neck connects pseudoaneurysm to artery
  - Characteristic "to and fro" spectral pattern at narrow aneurysm neck
  - Characteristic "yin-yang" sign on color Doppler imaging
    - Swirling flow seen as different color signals within lesion
  - Lumen may not be fully filled with color due to partial thrombosis
  - Slow flow may occasionally be seen

Ganglion Cyst



Longitudinal ultrasound shows a ganglion cyst on the dorsum of radioscaphoid articulation. The tortuous stalk extends deeply toward the radioscaphoid articulation. The distal radius and scaphoid are normal.

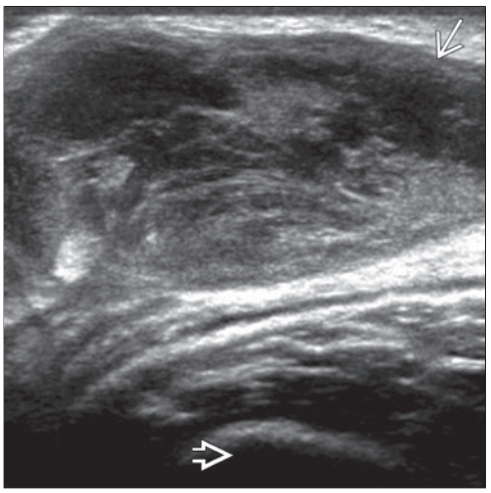
Ganglion Cyst



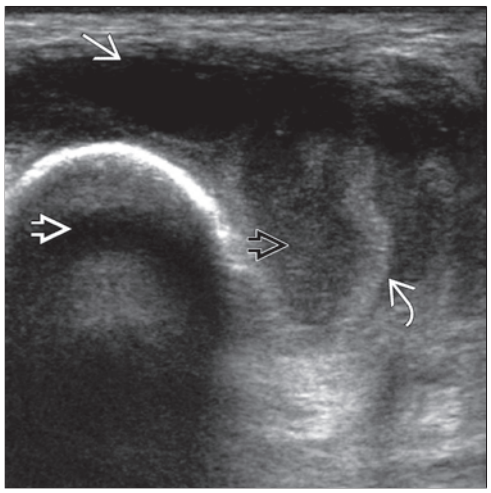
Transverse ultrasound shows a ganglion cyst on the volar aspect of the middle finger proximal phalanx. The ganglion lies volar to the flexor tendon.

CYSTIC SOFT TISSUE MASS

Bursal Distension

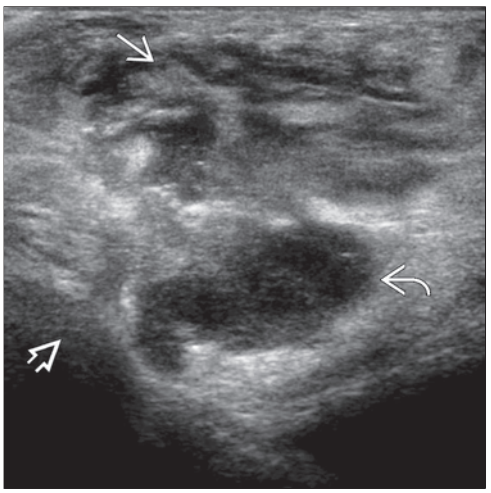


Bursal Distension

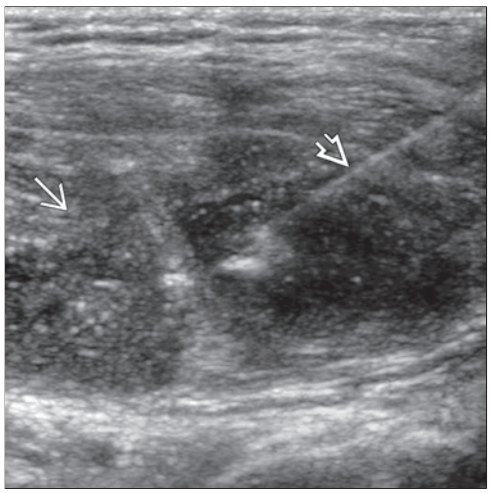


(Left) *Transverse ultrasound of the buttock region shows a large, cystic mass filled with inflammatory material overlying the ischial tuberosity due to a distended ischial tuberosity bursa.* ***(Right)*** *Transverse ultrasound of the elbow region shows a large, cystic mass overlying the olecranon process due to olecranon bursitis. There is septation and fine echoes within the bursa due to blood or proteinaceous inflammatory fluid.*

Abscess

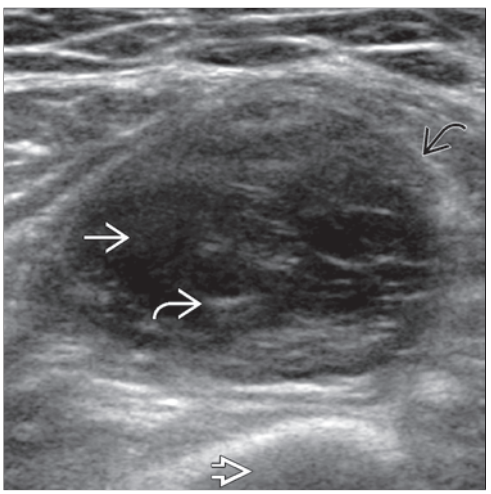


Abscess

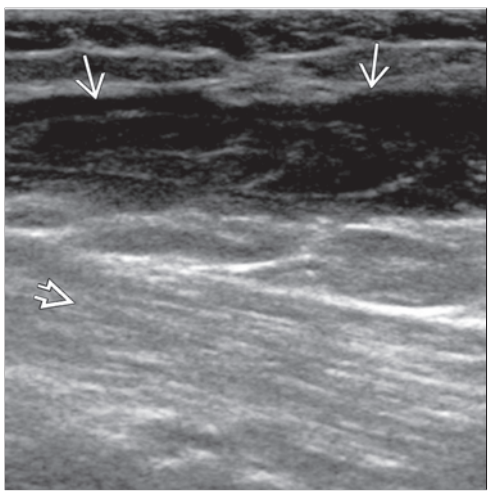


(Left) *Transverse ultrasound of the buttock shows a large abscess within the subcutaneous tissues and the gluteal muscle. The sacrum is normal. Ultrasound-guided aspiration yielded staphylococcus aureus.* ***(Right)*** *Transverse ultrasound of an intravenous drug user shows a large, irregular abscess cavity within the gluteus maximus muscle. Percutaneous needle aspiration for culture is being undertaken.*

Hematoma

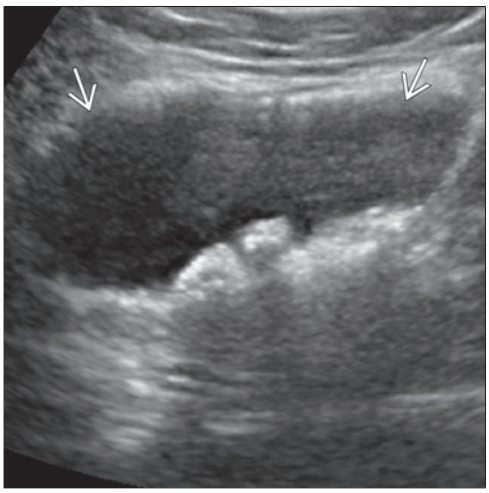


Hematoma

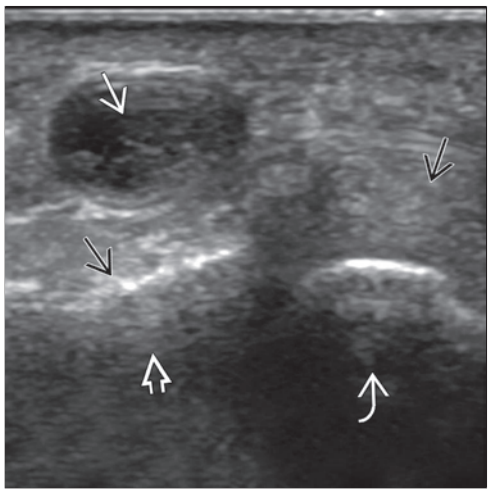


(Left) *Transverse ultrasound shows an organizing hematoma within the posterior thigh muscle. There is cystic change and septation within the hematoma. The femoral shaft is normal.* ***(Right)*** *Transverse ultrasound shows a liquefied hypoechoic hematoma in the subcutaneous tissues of the calf. The hematoma lies superficial to the calf muscles. Hematoma can be hyperechoic, hypoechoic, or cystic depending on the chronicity.*

Seroma

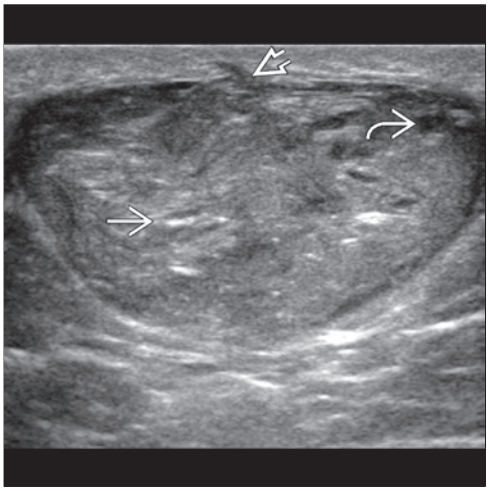


Dermoid/Implantation Dermoid



(Left) *Transverse ultrasound of the proximal thigh in a patient 1 month following a hip replacement shows a large, cystic collection located in the deep subcutaneous region. Aspiration confirmed sterile fluid.* ***(Right)*** *Longitudinal ultrasound shows a cystic implantation dermoid in the finger pulp. The lesion lies superficial to the flexor digitorum profundus tendon. Note the base of the distal phalanx and the head of the middle phalanx.*

Epidermoid Cyst

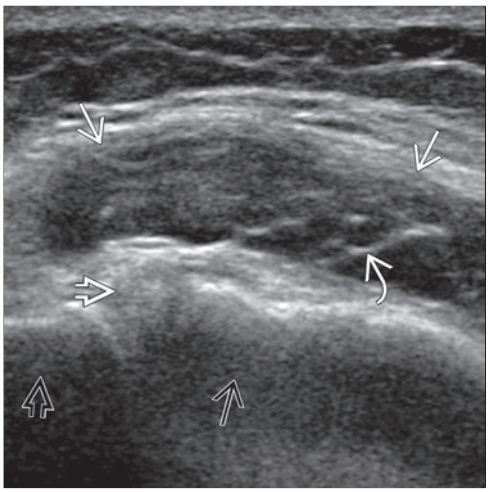


Epidermoid Cyst

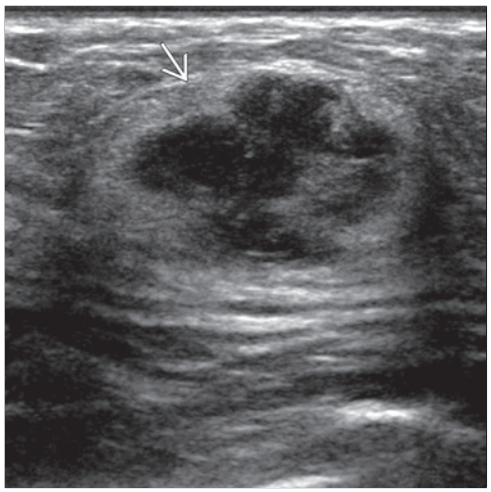


(Left) *Longitudinal ultrasound shows an epidermoid cyst with a well-circumscribed, ovoid heterogeneous nodule containing internal, hyperechoic, disc-like areas, small hypoechoic areas, and a hypoechoic track extending toward the skin.* ***(Right)*** *Longitudinal ultrasound shows an epidermoid cyst as a well-circumscribed hypoechoic nodule with dermal attachment, internal filiform anechoic areas, linear hyperreflective areas, and posterior acoustic enhancement.*

Parameniscal Cyst



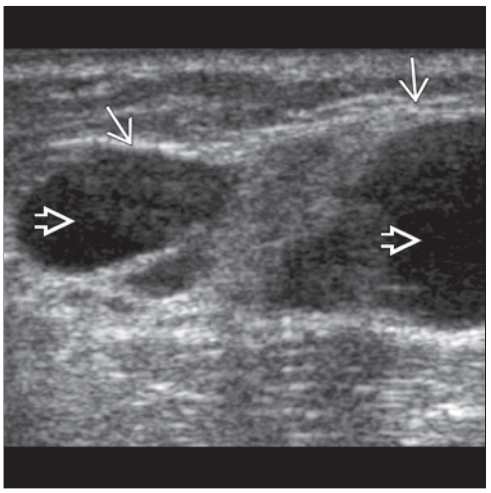
Metastasis



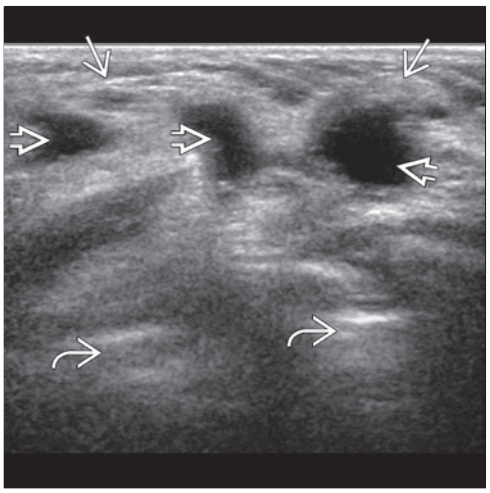
(Left) *Longitudinal ultrasound shows a large parameniscal cyst at the medial tibiofemoral articulation. There is septation within the cyst. Note the periphery of the medial meniscus between the distal femur and the proximal tibia.* ***(Right)*** *Longitudinal ultrasound of the chest wall of a patient with high-grade conventional osteosarcoma of the knee shows an irregular, biopsy-proven, subcutaneous, cystic metastatic nodule.*

CYSTIC SOFT TISSUE MASS

Vascular Malformation

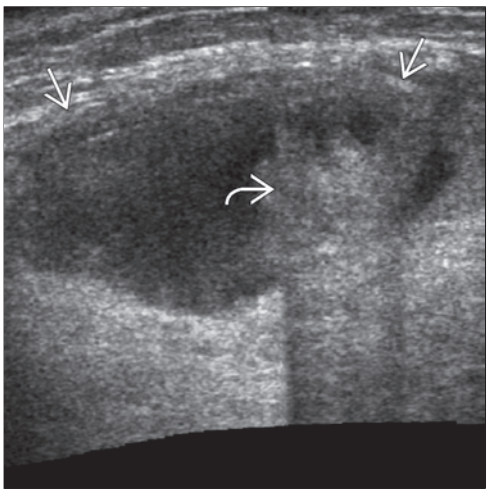


Lymphatic Malformation

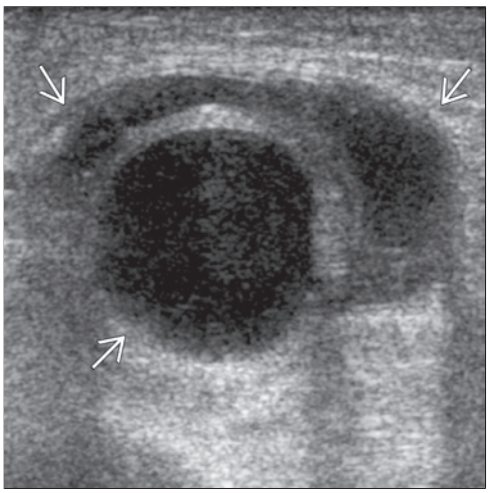


(Left) *Longitudinal ultrasound of the leg in an adult patient shows a well-defined, subcutaneous, cystic mass with minimal marginal vascularity (not shown), consistent with slow-flow vascular malformation containing dilated vascular channels.* ***(Right)*** *Longitudinal ultrasound of the chest wall shows a poorly defined lymphatic malformation with a cystic component and poorly defined supporting stroma. The underlying ribs are normal.*

Fat Necrosis

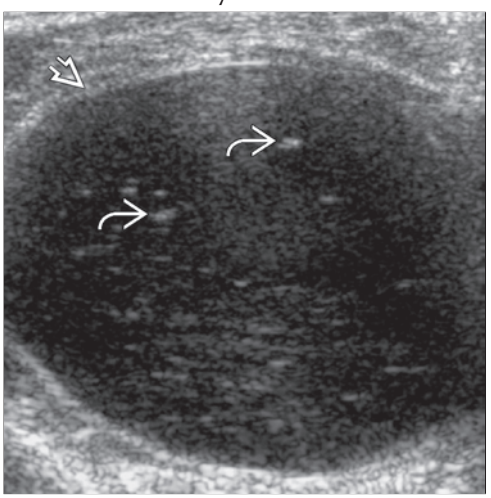


Schwannoma

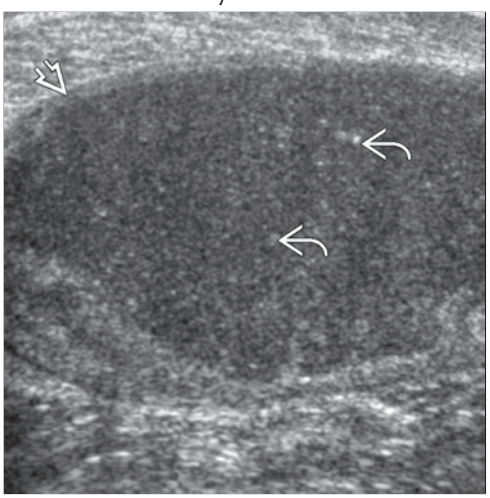


(Left) *Longitudinal ultrasound of the buttock 1 month following blunt trauma shows a well-defined, largely cystic, subcutaneous mass with early calcification consistent with liquefied fat necrosis.* ***(Right)*** *Transverse ultrasound shows a multilayered cystic mass in the calf muscle. This mass was continuous with the tibial nerve. Biopsy confirmed a cystic schwannoma.*

Myxoma

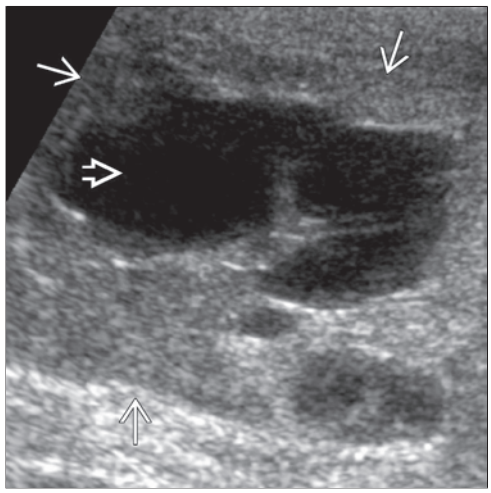


Myxoma

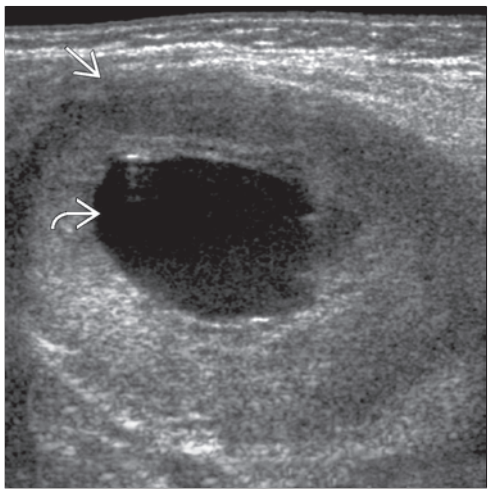


(Left) *Transverse ultrasound shows a well-defined myxoid tumor within the thigh muscle. Many small, fine, internal echoes due to colloid aggregates are present. Histology confirmed a myxoma.* ***(Right)*** *Transverse ultrasound shows a well-defined myxoid tumor within the soleus muscle. Many small, fine, internal echoes are present, some with "comet tail" artifacts. These are colloid aggregates and may be seen in myxoma or ganglia.*

Sarcoma

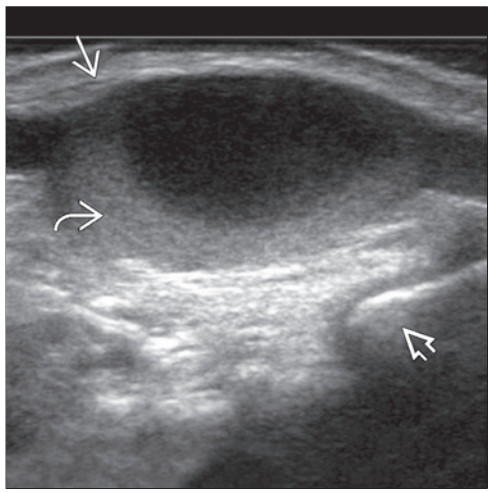


Lymph Node

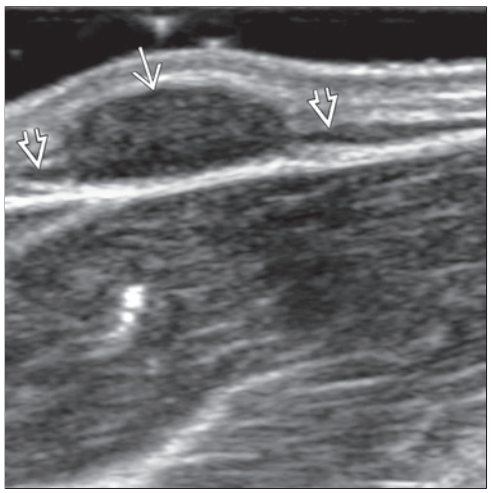


(Left) *Longitudinal ultrasound shows a large, deep-seated mass in the shoulder region. There are hyperechoic cystic or myxoid areas present. Biopsy confirmed malignant fibrous histiocytoma.* ***(Right)*** *Transverse ultrasound of the groin region shows a large, metastatic, inguinal node with a central, cystic necrotic area from an alveolar soft part sarcoma of the thigh.*

Venous Varix

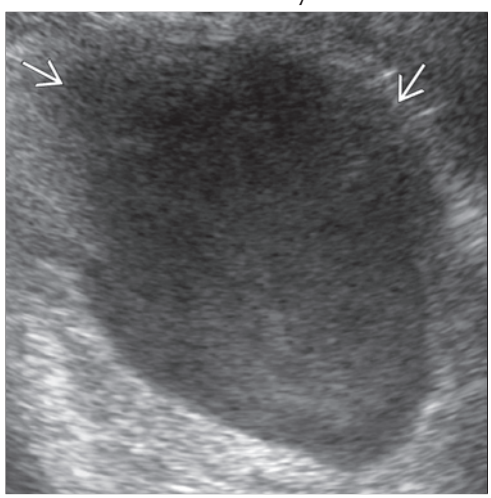


Venous Varix

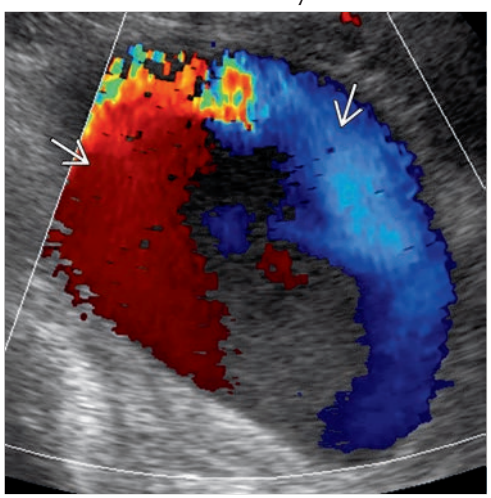


(Left) *Longitudinal ultrasound shows a venous varix on the dorsal aspect of the wrist. There is partially stagnant flow within the varix, which mimics a hypoechoic mass. Dynamic ultrasound with compression/decompression revealed movement within this stagnant flow area. The distal radius is normal.* ***(Right)*** *Longitudinal ultrasound shows a fusiform-shaped venous varix of a superficial vein on the medial aspect of the elbow.*

Pseudoaneurysm



Pseudoaneurysm



(Left) *Transverse ultrasound shows a large cystic lesion along the path of the superficial femoral artery in the distal thigh medially.* ***(Right)*** *Transverse ultrasound of the same patient shows a typical "yin-yang" sign. Features are compatible with a pseudoaneurysm of the superficial femoral artery. A "to and fro" spectral pattern was present at the pseudoaneurysm neck (not shown).*

CALCIFIED SOFT TISSUE MASS

DIFFERENTIAL DIAGNOSIS

Common
- Venous Vascular Malformation
- Granuloma
- Gout or Pseudogout

Less Common
- Fat Necrosis
- Panniculitis
- Pilomatricoma
- Sarcoma
- Soft Tissue Metastases
- Nerve Sheath Tumor
- Fibroma
- Soft Tissue Chondroma
- Hematoma
- Calcifying Aponeurotic Fibroma
- Myositis Ossificans
- Tumoral Calcinosis
- Dermatomyositis
- Calcific Myonecrosis
- TB Abscess
- Parasitic Infestation
- Heterotopic Ossification
- Sclerodactyly

ESSENTIAL INFORMATION

Key Differential Diagnosis Issues
- Visibility of lesion on ultrasound very dependent on level of calcification
  - Heavy peripheral calcification → only superficial margin visible
  - Light peripheral calcification → much of lesion visible
  - Mild matrix mineralization → most of lesion visible
- Align transducer obliquely to obtain views not obscured by calcification
- Review radiographs ± computed tomography as they are very helpful for analyzing type of calcification

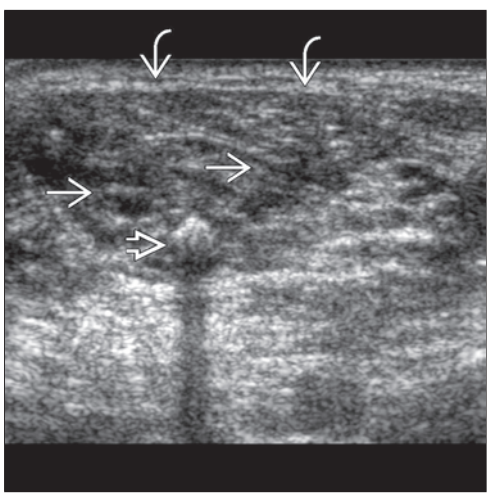
Helpful Clues for Common Diagnoses
- **Venous Vascular Malformation**
  - Calcified phleboliths common but not invariable feature
    - More common with slow-flowing vascular malformations
    - Represent calcified thrombi
  - Small- to medium-sized phleboliths, depending on size of vein
    - Echogenic with acoustic shadowing
    - Ultrasound more sensitive than radiographs for detection
  - Typical features include vascular channels, compressibility, venous flow ± infiltrative margin
- **Granuloma**
  - Commonly located in subcutaneous tissues of buttock and frequently multiple
    - Often have history of previous subcutaneous injection at site
  - Variable rim calcification → posterior acoustic shadowing
  - Typically well-defined hypoechoic mass in subcutaneous peripheral soft tissue
  - Rounded hypoechoic mass
    - Posterior margin may not be visualized due to dense posterior acoustic shadowing
    - Width dimension is similar to depth dimension as the lesion is rounded in appearance
  - Typically little or no hyperemia on Doppler imaging
  - ± indentation of adjacent investing fascia or muscle when large
- **Gout or Pseudogout**
  - Located around joints, ligament, and fascial insertions
    - Tophi more common with gout
    - Pseudogout → hydroxyapatite deposition
  - Soft tophi or deposits contain little mineralized component
    - "Comet tail" artifacts secondary to crystal aggregates
  - Hard tophi or deposits often heavily mineralized
    - Dense posterior acoustic shadowing limits ultrasound assessment

Helpful Clues for Less Common Diagnoses
- **Fat Necrosis**
  - Subcutaneous fat is prone to trauma, particularly on anterolateral aspect of thigh, lateral aspect arm, and gluteal region
  - Blunt subcutaneous trauma → injury and necrosis of fat cells
    - → focal swelling and edema of subcutaneous tissues
    - → reparative change with mild localized hyperemia on color Doppler imaging
    - → encapsulated fat necrosis ± heterotopic ossification ± fibrosis
  - More severe forms of fat necrosis tend to undergo calcification and ossification
  - Other typical features: Hyperechoic fat containing hypoechoic spaces (infarcted fat)
- **Panniculitis**
  - Calcification or ossification of fat occurs following panniculitis (panniculitis ossificans)
    - Difficult to distinguish from fat necrosis
- **Pilomatricoma**
  - Benign skin neoplasm with differentiation toward hair matrix
  - Round, well-defined, heterogeneous, hypoechoic mass with partially calcified rim and posterior acoustic shadowing
    - Some lesions may be completely calcified
    - ± peripheral hypoechoic halo ± mild peripheral hyperemia on color Doppler
- **Sarcoma**
  - Benign and malignant soft tissue tumors may calcify
  - Calcification may be intrinsic to tumor or may represent residual bone in sarcoma extending from or invading bone
  - Synovial sarcoma is most common malignant soft tissue tumor to calcify
    - ~ 50% show foci of calcification
  - Other sarcomas that contain foci of calcification include
    - Liposarcoma, malignant fibrous histiocytoma, extraskeletal osteosarcoma, leiomyosarcoma, and alveolar soft part sarcoma
- **Soft Tissue Metastases**
  - Soft tissue metastases that contain foci of calcification usually arise from

- Adenocarcinoma of colon, stomach, or pancreas
- Medullary carcinoma of thyroid and ovarian carcinoma

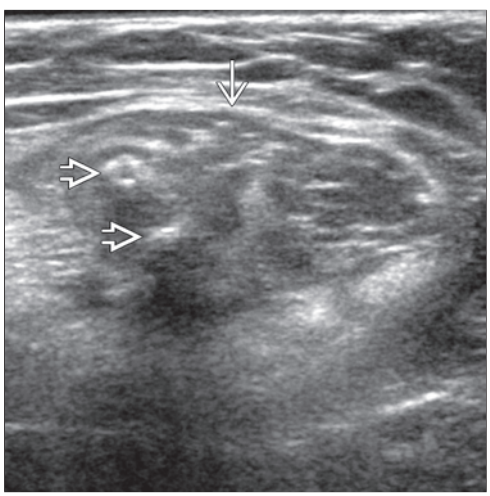
- **Nerve Sheath Tumor**
  - Calcification uncommon; if calcification, pathognomonic for ancient schwannoma
  - Typical features: Well-defined, hypoechoic, hypervascular lesion in continuity with nerve, which may be thickened close to tumor
- **Fibroma**
  - Subcutaneous fibrous nodules that may calcify or ossify
  - Not locally aggressive
- **Soft Tissue Chondroma**
  - Often quite heavily calcified at periphery, limiting visibility
    - Well-defined hypoechoic rim of cartilage visible beyond echogenic calcified front
    - Mild or absent hyperemia on color Doppler
- **Hematoma**
  - Rarely can show peripheral calcification
- **Calcifying Aponeurotic Fibroma**
  - a.k.a. juvenile aponeurotic fibroma
  - Locally aggressive fibroblastic tumor of children and young adults, usually located in hands and feet
    - Occur next to dense fibrous connective tissue (fascia or periosteum)
    - May erode bone
  - Nodular or ill-defined infiltrating mass with fine stippled calcification
    - ~ 50% recur after resection
- **Myositis Ossificans**
  - Heterotopic bone and cartilage formation that is typically located within muscle
  - Due to trauma, burns, or cerebrospinal disorder
  - Muscle tear with hemorrhage, then cystic transformation
    - 1st week: Heterogeneous hypoechoic irregular focus within muscle
    - Weeks: Peripheral echogenic rim
    - Months: Hyperechoic band adjacent and parallel to cortex or irregular echogenic foci
- **Tumoral Calcinosis**
  - Calcium deposits in periarticular (> shoulder, hip, and elbow) soft tissues
  - Lobulated, well-defined, calcified mass along extensor surfaces of large joints
  - Seen in renal failure ± familial component
- **Dermatomyositis**
  - Idiopathic inflammatory myopathy and dermopathy
  - Especially large muscle groups, upper > lower limbs
  - Increased risk of malignancy, especially in elderly men (30% risk)
  - Typical feature is diffuse calcification of symptomatic muscles
- **Calcific Myonecrosis**
  - Post-traumatic condition in which single muscle is replaced by enlarging mass with central liquefaction and peripheral calcification
  - Probably due to compartment syndrome
  - Many decades may exist between trauma and symptom onset
  - Typical feature is muscle calcification at anterior compartment of leg
- **TB Abscess**
  - "Cold abscess" with insidious onset
  - Contains calcifying caseating granulomatous material
- **Parasitic Infestation**
  - Cysticercosis
    - Multiple intermuscular "rice grain" calcifications oriented along direction of muscle fibers
  - Dracunculiasis (Guinea worm)
    - Small crescentic calcifications, feet, hands, groin
- **Heterotopic Ossification**
  - More common around hips or elbows, following trauma or joint replacement
- **Sclerodactyly**
  - Subcutaneous and periarticular calcification associated with tightening of skin, subcutaneous atrophy, acro-osteolysis
  - Hands > feet
  - Often associated with scleroderma; also associated with graft-vs.-host disease and Raynaud disease

Venous Vascular Malformation



Transverse ultrasound shows a venous malformation with multiple small tubular spaces representing dilated vascular channels and a phlebolith with strong acoustic shadowing.

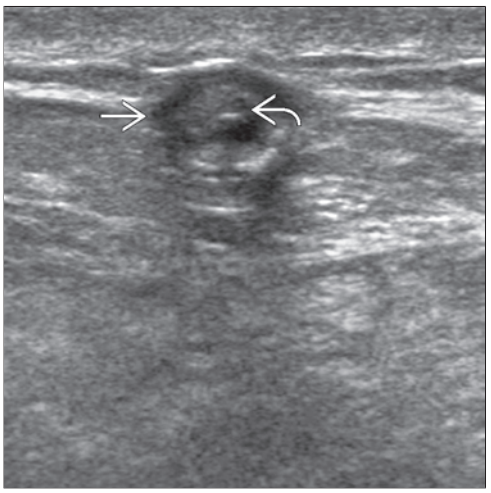
Venous Vascular Malformation



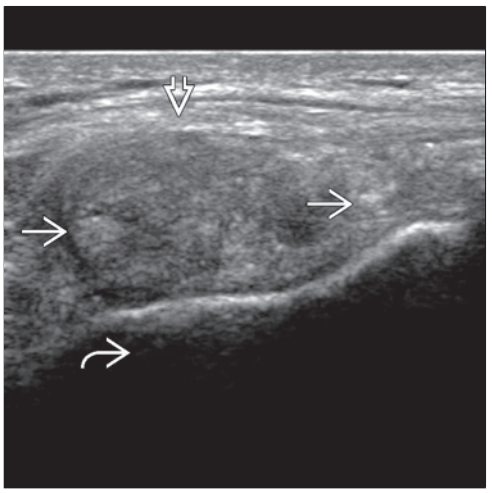
Transverse ultrasound shows a heterogeneous intramuscular mass in the forearm. Echogenic phleboliths with mild posterior acoustic shadowing with mild color Doppler flow (not shown) are present.

CALCIFIED SOFT TISSUE MASS

Granuloma

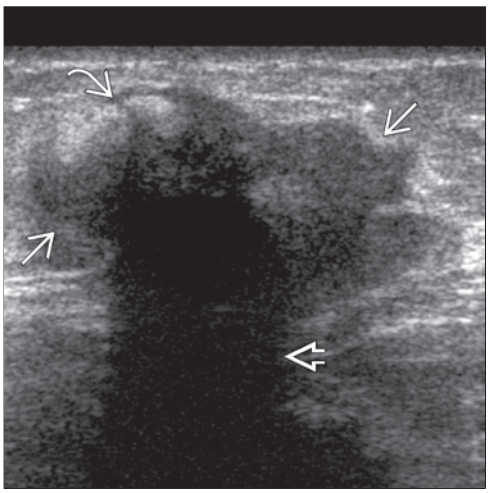


Gout or Pseudogout

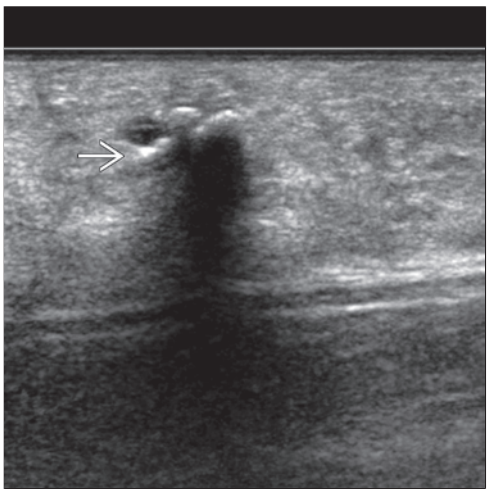


(Left) *Transverse ultrasound shows a small subcutaneous injection granuloma of the buttock. There is minimal calcification present. Other injection granulomas may be much more heavily calcified.* ***(Right)*** *Oblique ultrasound of the knee joint shows a gouty tophus with echogenic crystal aggregates on the lateral aspect of the distal femur. This is a soft tophus. Hard tophi show more extensive and denser calcification.*

Fat Necrosis

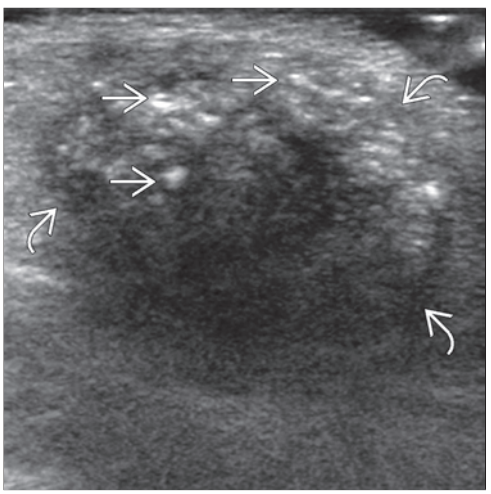


Panniculitis

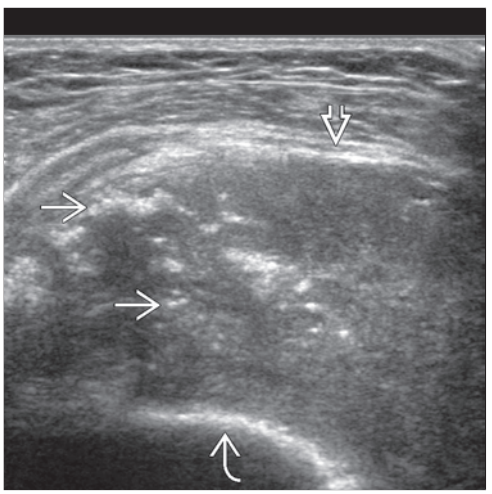


(Left) *Transverse ultrasound of a buttock shows an area of fat necrosis seen as a well-defined, subcutaneous, hypoechoic mass. There is prominent calcification with dense acoustic shadowing.* ***(Right)*** *Longitudinal ultrasound of a nontraumatic tender leg nodule shows a hypoechoic, heavily calcified subcutaneous nodule. Color Doppler imaging (not shown) showed minimal perilesional hyperemia. Histology was compatible with panniculitis ossificans.*

Pilomatricoma



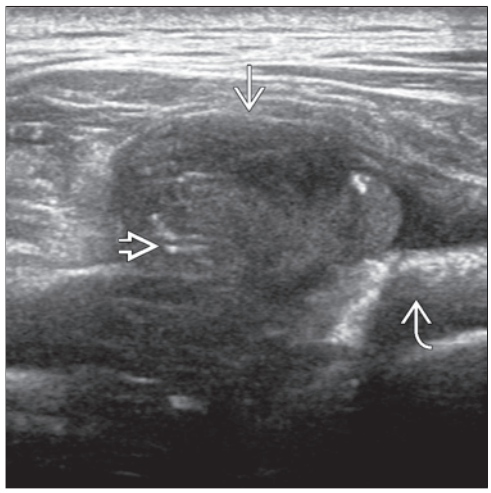
Sarcoma



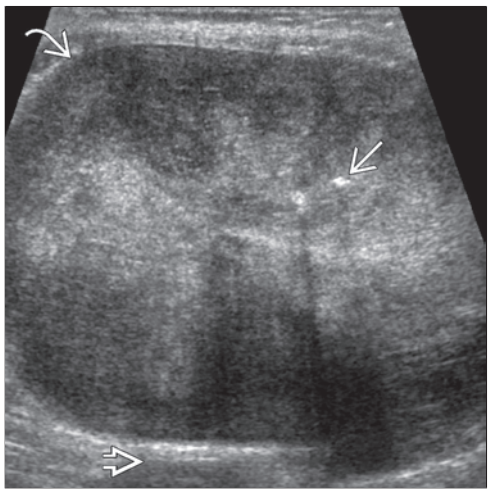
(Left) *Transverse ultrasound of pilomatricoma shows a heterogeneous subcutaneous mass containing multiple lumpy calcifications associated with moderate posterior shadowing. There is a thin hypoechoic peripheral rim.* ***(Right)*** *Transverse ultrasound shows a large tumor mass in the distal thigh adjacent to the femur. Multiple foci of calcification are present within the mass. Biopsy confirmed a spindle cell sarcoma.*

CALCIFIED SOFT TISSUE MASS

Soft Tissue Metastases



Nerve Sheath Tumor

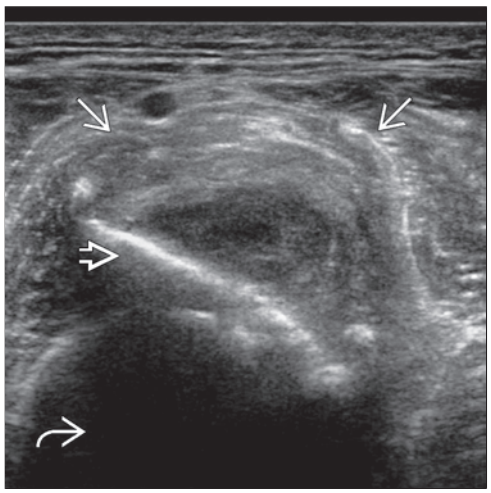


(Left) *Transverse ultrasound of a paraspinal mass shows a discrete hypoechoic mass with several small calcific foci adjacent to the transverse process. Biopsy showed metastatic squamous cell carcinoma from a known lung primary.* ***(Right)*** *Longitudinal ultrasound of a mass on the lateral aspect of the leg, which had been slowly growing for 10 years, shows a large peroneal nerve sheath tumor with small foci of calcification. The fibula is deep to the tumor.*

Soft Tissue Chondroma

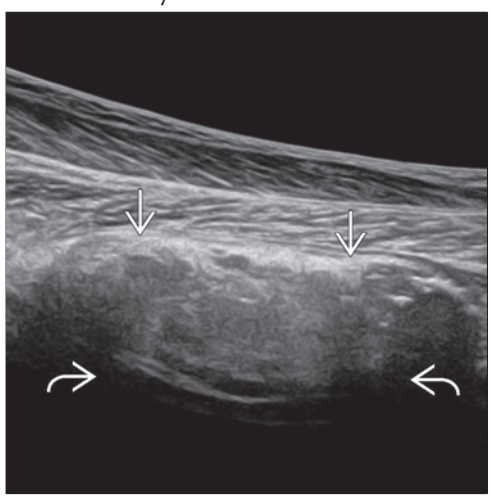


Hematoma

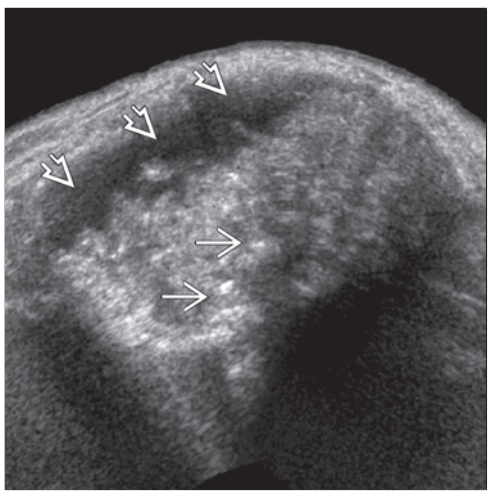


(Left) *Transverse ultrasound of the wrist shows a large heavily calcified mass with severe posterior acoustic shadow. Biopsy confirmed a chondroma.* ***(Right)*** *Transverse ultrasound of the midfemur shows a moderate-sized chronic hematoma with dystrophic calcification adjacent to the femur. The center of the hematoma seems partially liquefied.*

Myositis Ossificans



TB Abscess



(Left) *Panoramic ultrasound scan shows a large, heavily calcified calf muscle mass. The calcification is predominantly at the periphery of the mass, causing moderate to severe posterior acoustic shadowing. The appearances are those of myositis ossificans.* ***(Right)*** *Transverse ultrasound shows a large, partially liquefied soft tissue mass in the thigh with dependent echogenic debris. Ultrasound-guided aspiration for culture confirmed a TB abscess.*

HYPERVASCULAR SOFT TISSUE MASS

DIFFERENTIAL DIAGNOSIS

Common
- Vascular Anomaly
- Nerve Sheath Tumor
- Soft Tissue Sarcoma

Less Common
- Glomus Tumor
- Granulation Tissue and Inflammatory Mass
- Vascular Leiomyoma
- Pilomatricoma
- Metastases
- Fibroma
- Giant Cell Tumor of Tendon Sheath
- Panniculitis
- Focal Myositis
- Lymph Nodes
- Lymphoma
- Diabetic Muscle Infarction

ESSENTIAL INFORMATION

Key Differential Diagnosis Issues
- Vascularity can be assessed on grayscale, color Doppler, and power Doppler imaging
  - Grayscale useful for assessing slow venous flow
  - Color Doppler provides information about flow direction but not as sensitive as power Doppler in detection of flow
    - Power Doppler does not assess flow direction
  - Additional spectral analysis is usually not helpful or necessary
- Apply minimal transducer pressure to avoid effacing vasculature
- Note whether vascularity pattern is predominantly central or peripheral, organized, chaotic, or mixed pattern
- Color Doppler is not quite as sensitive to hyperemia as contrast enhancement on MR or CT
  - Contrast enhancement on MR or CT is also dependent on features such as permeability and interstitial flow

Helpful Clues for Common Diagnoses
- **Vascular Anomaly**
  - For all vascular malformations, determine
    - Size and location of lesion
    - Predominant vascular type (arterial/venous capillary)
    - Relative amount of vascular vs. stromal tissue
    - Presence of phleboliths or recognizable area of thrombosis
  - Lesion characteristics and flow best assessed with ultrasound
    - Lesion extent (of large and ill-defined lesions) and multiplicity best assessed with MR imaging
  - 2 main types of vascular anomaly, which vary regarding age of onset and clinical course
  - Hemangioma
    - Present at birth and grows during childhood
    - Involutes spontaneously after childhood
    - Proliferation → stabilization → involution
  - Vascular malformation
    - Grow proportional to patient growth
    - More rapid growth precipitated by puberty, pregnancy, trauma
    - 3 main types of vascular malformation with considerable overlap: Capillary, venous, and arteriovenous
- **Nerve Sheath Tumor**
  - Hypoechoic, typically fusiform shaped
  - ± anechoic areas due to myxoid deposition
    - ± hyperechoic areas due to hemorrhage, calcification, or fibrosis
  - Posterior acoustic enhancement
  - Variable vascularity, which diminishes with increasing transducer pressure
    - Most show moderate to high vascularity
    - Rarely no detectable vascularity
- **Soft Tissue Sarcoma**
  - Usually hypervascular
    - Cannot predict aggressiveness of lesion based on degree or pattern of vascularity
  - Occasionally hypo- or avascular
    - Particularly fibrosarcoma or liposarcoma
  - Alveolar soft part sarcoma may mimic vascular malformation on imaging

Helpful Clues for Less Common Diagnoses
- **Glomus Tumor**
  - Most common location: Distal extremities, especially subungual areas
    - Hypoechoic, hypervascular nodule between nail & cortex of distal phalanx
  - Arises from glomus body, which is arteriovenous shunt in dermis that contributes to temperature regulation
  - Glomus tumors also arise in areas outside of dermis that do not normally contain glomus cells
    - May arise from perivascular cells that can differentiate into glomus cells
    - Seen as small, well-defined, hypoechoic, hypervascular mass
- **Granulation Tissue and Inflammatory Mass**
  - Hypoechoic irregular tissue
  - Seen in infection, reparative scar tissue, or around foreign body
  - Usually moderately to highly vascularized
- **Vascular Leiomyoma**
  - Benign solitary smooth muscle neoplasm that most commonly occurs in subcutaneous soft tissues of lower extremity
    - 2/3 involve lower leg or ankle
  - Well-defined smooth margin
  - Usually round or ovoid in shape with long axis parallel to extremity axis
  - Hypoechoic, homogeneous without perceivable capsule
  - Mild to moderate posterior enhancement
  - Occurs in close proximity to artery or vein
  - Hypervascular with peripheral vascular convergence
- **Pilomatricoma**
  - Benign skin tumor arising from cells of hair matrix
  - Mass extending from dermal to subcutaneous tissues
  - Well-circumscribed, ovoid, heterogeneous, solid subdermal mass containing matrix calcification, intrinsic vascularity, and peripheral hypoechoic rim
    - Hypoechoic peripheral rim due to connective tissue capsule
    - Intrinsic vascularity that may be peripheral, central, or mixed peripheral and central

- Ultrasound appearances sufficiently specific to make diagnosis in most cases

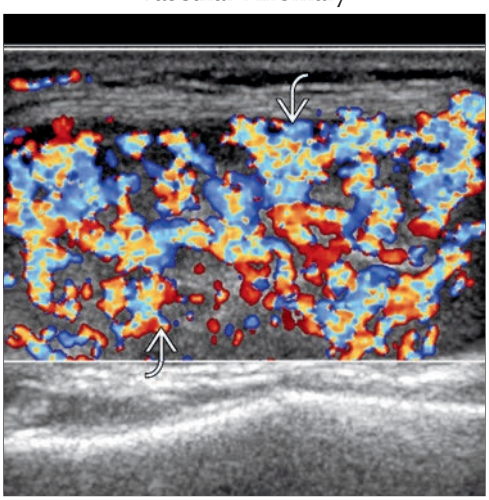
- **Metastases**
  - Manifestation of end-stage metastatic disease
  - Ultrasound appearances are similar to soft tissue sarcoma, though metastases present at smaller size than sarcomas
    - Metastases more painful than sarcomas
  - Adenocarcinoma is most common cell type
    - Carcinoma of breast and lungs are most common primaries
  - Most common site: Lower limb muscles
    - Biopsy is necessary for diagnosis
- **Fibroma**
  - Localized tumorous collection of collagen with sparse number of fibroblasts
    - Nuchal fibromas in midline nape of neck
    - Tendon sheath fibromas of hands and feet
- **Giant Cell Tumor of Tendon Sheath**
  - Mostly eccentrically located to tendon growing along length of tendon sheath
  - Moderately to highly vascular
  - Hypoechoic, peritendinous in location
- **Panniculitis**
  - Localized inflammation of subcutaneous fat due to infection, systemic inflammatory disorder, myeloproliferative disorder, pancreatic disease, drug hypersensitivity, or Weber-Christian disease
  - Localized area of altered echogenicity and thickness of subcutaneous fat with loss of normal fat lobulation
    - Thickening and hyperechogenicity of subcutaneous fat in early or active stage of disease with mild to moderate hyperemia
    - Atrophy and hypoechogenicity of subcutaneous fat in chronic or inactive stage of disease with little or no hyperemia
- **Focal Myositis**
  - Ill-defined area of affected muscle is hyper- or hypoechoic with hyperemia
    - Underlying muscle architecture visible in early stages
  - Manifestation of generalized inflammatory arthropathy such as Behçet disease
  - MR is more sensitive than ultrasound for diagnosis
- **Lymph Nodes**
  - Lymph node enlargement seen with reactive, infective, metastatic, or lymphomatous nodes
  - Degree and pattern of hypervascularity depends on etiology of nodal enlargement
  - Reactive or infective nodes show moderately increased hilar flow pattern
    - Elongated shape, preservation of central fatty hilum, and smooth border, with absence of matting or necrosis
    - Tuberculous nodes may show necrosis, obliteration of hilar vessels ± capsular vascularity
  - Malignant nodes show variable peripheral vascularity or mixed hilar and peripheral flow pattern
    - Rounded shape, obliteration of central fatty hilum, ± extracapsular spread with matting or necrosis
- **Lymphoma**
  - Lymphoma classified as Hodgkin or non-Hodgkin lymphoma
    - Non-Hodgkin lymphoma classified as T-cell or B-cell neoplasms
  - 30% of lymphoma is extranodal with most common musculoskeletal involvement being bone and muscle
  - Involvement of superficial tissues uncommon
    - Subcutaneous panniculitis-like T-cell lymphoma is uncommon type of peripheral T-cell lymphoma
  - Moderate to high vascularity
- **Diabetic Muscle Infarction**
  - Seen in end-stage diabetes with established vasculopathy
  - Hypovascular stage → hypervascular stage after about 10 days
    - Ill-defined hypoechoic area evolves into better-defined hypoechoic area
    - Underlying muscle architecture remains visible
    - Hyperemia feature of recovery phase of diabetic muscle infarction

Vascular Anomaly



Transverse ultrasound shows a well-defined, lobulated soft tissue mass with predominant fatty stroma in the cheek of an infant. There are only a few vascular channels visible.

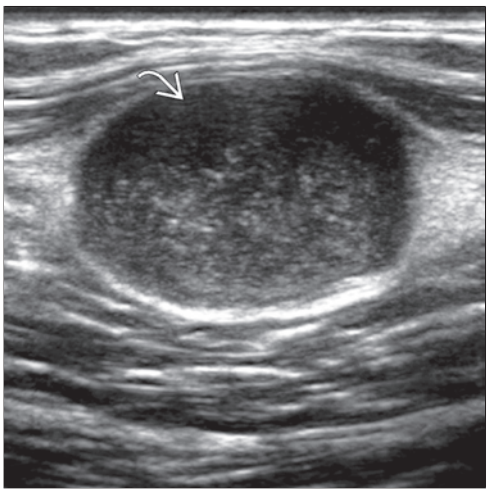
Vascular Anomaly



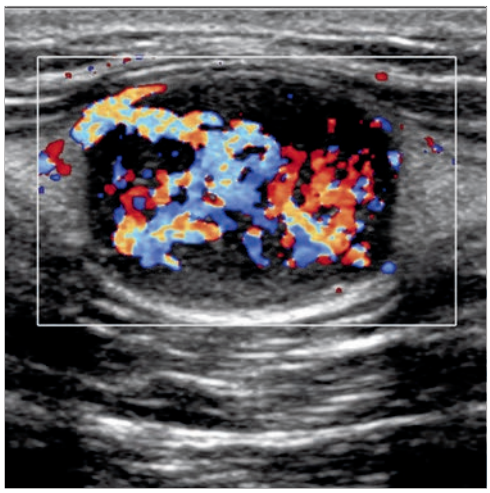
Longitudinal color Doppler US of same lesion shows high-flow vascular anomaly. Clinical course was consistent with a high-flow infantile hemangioma. Most of the arteries are too small to be resolved on grayscale US.

HYPERVASCULAR SOFT TISSUE MASS

Nerve Sheath Tumor

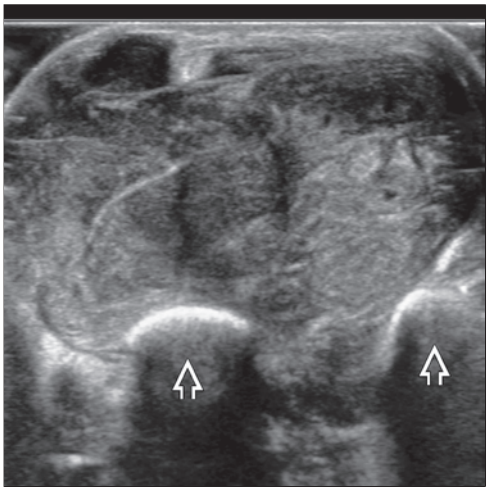


Nerve Sheath Tumor

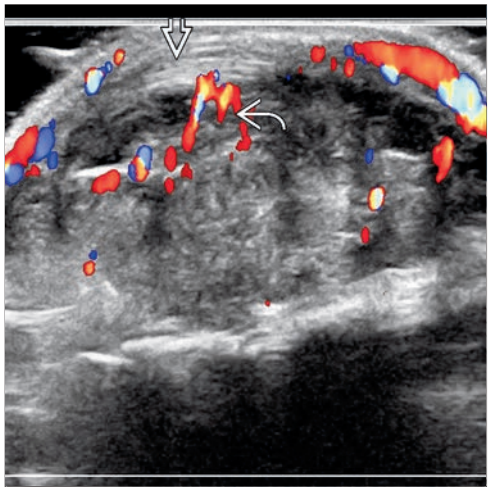


(Left) *Longitudinal ultrasound shows a well-defined, intramuscular hypoechoic mass with mild posterior acoustic enhancement.* ***(Right)*** *Longitudinal color Doppler ultrasound of the same mass shows a high degree of disorganized vascularity within the nerve sheath tumor.*

Soft Tissue Sarcoma

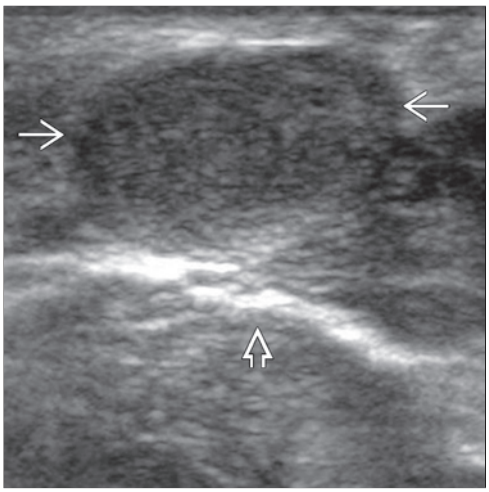


Soft Tissue Sarcoma

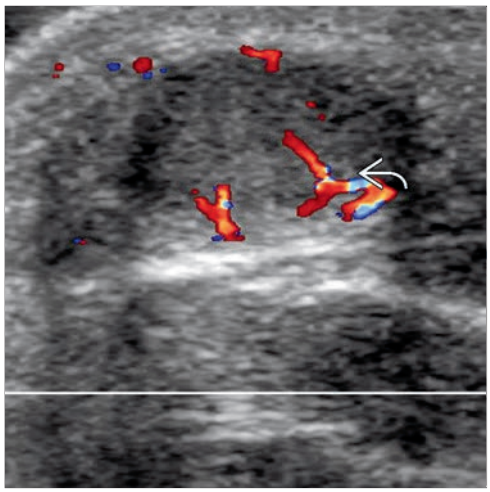


(Left) *Transverse ultrasound shows a large soft tissue mass on the dorsum of the hand extending deeply between the 4th & 5th metacarpal bones with smooth bony scalloping.* ***(Right)*** *Longitudinal color Doppler ultrasound of the same tumor shows moderate tumor hyperemia. The mass has arisen deep to the extensor tendons, which are displaced superficially. Percutaneous biopsy for histology revealed a clear cell sarcoma.*

Glomus Tumor



Glomus Tumor

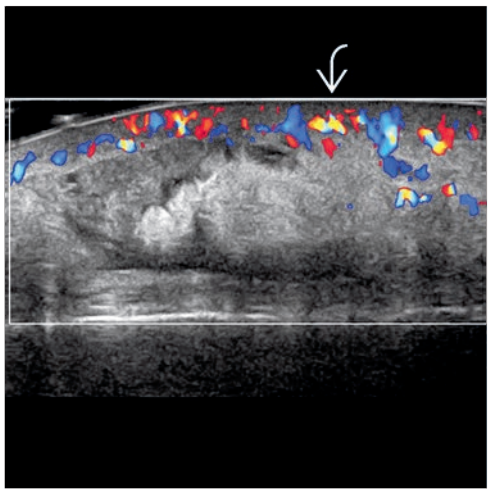


(Left) *Longitudinal ultrasound of a patient with a painful mass shows a well-defined hypoechoic nodule of the hypothenar region. The nodule is abutting the 5th metacarpal bone.* ***(Right)*** *Longitudinal color Doppler ultrasound of the same patient shows a mild degree of intratumoral hyperemia. The lesion was excised, and histology revealed a glomus tumor.*

Granulation Tissue and Inflammatory Mass

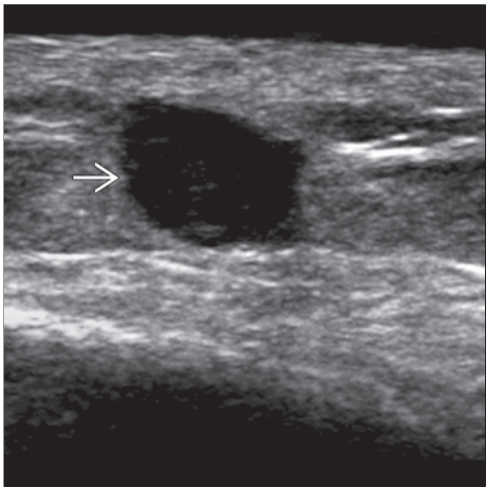


Granulation Tissue and Inflammatory Mass

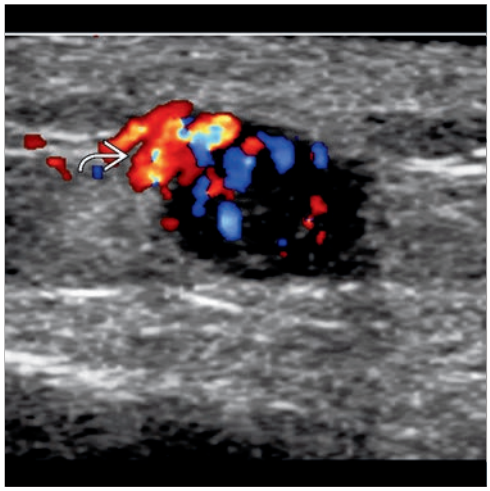


(Left) *Longitudinal ultrasound of the leg in a patient with clinically suspected infection of the shin shows a large subcutaneous mass* ➔ *with marked surrounding edema. There are hypoechoic areas* ➔ *within the affected area, but no discrete liquefaction is present.* ***(Right)*** *Longitudinal color Doppler ultrasound of the same lesion shows a moderate degree of marginal hyperemia* ➔ *due to active soft tissue inflammation. Percutaneous biopsy revealed a chronic inflammatory granulomatous mass.*

Vascular Leiomyoma

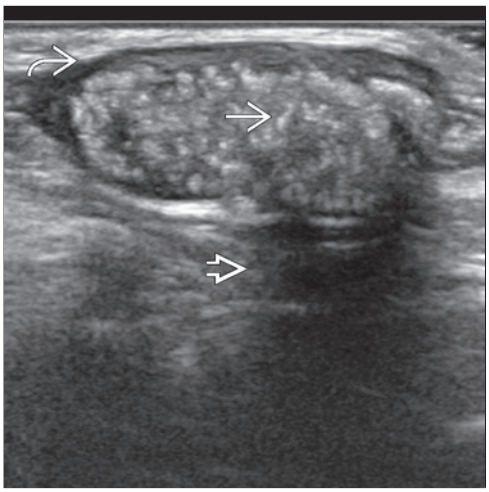


Vascular Leiomyoma

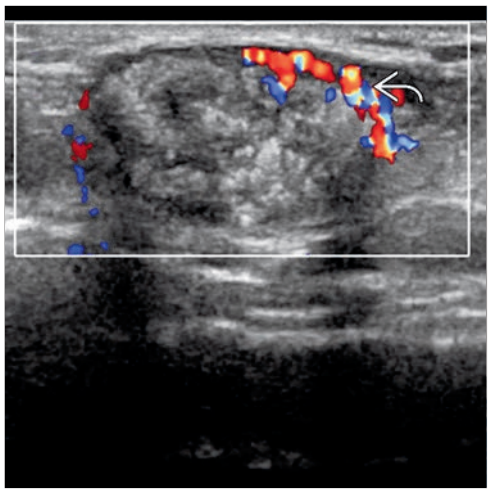


(Left) *Transverse ultrasound shows a subcutaneous vascular leiomyoma* ➔ *of the ankle region with a lobulated, mildly angular border. Note the characteristic hypoechoic echotexture of a vascular leiomyoma.* ***(Right)*** *Transverse color Doppler ultrasound of the same tumor reveals moderate peripheral and central vascularity with vascular convergence* ➔ *to the periphery of the nodule. This is quite characteristic of vascular leiomyoma.*

Pilomatricoma



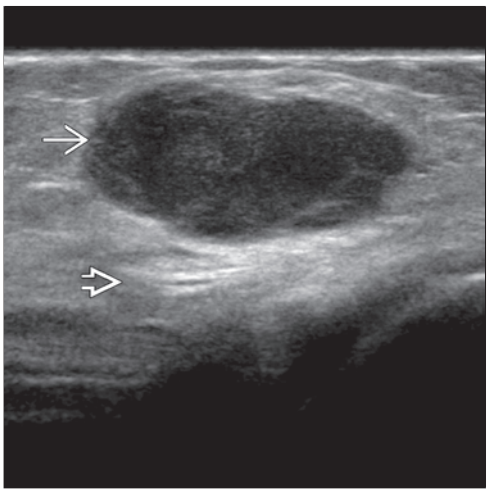
Pilomatricoma

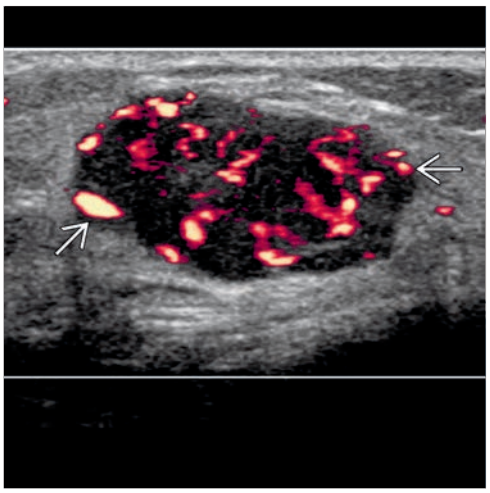


(Left) *Longitudinal ultrasound shows a well-defined, hypoechoic pilomatricoma with foci of matrix calcification* ➔, *mild posterior shadowing* ➔, *and a hypoechoic peripheral rim* ➔. *Pilomatricoma always occurs in the soft tissues rather than within joints or bone.* ***(Right)*** *Longitudinal color Doppler ultrasound of the same tumor shows mild to moderate peripheral vascularity* ➔.

HYPERVASCULAR SOFT TISSUE MASS

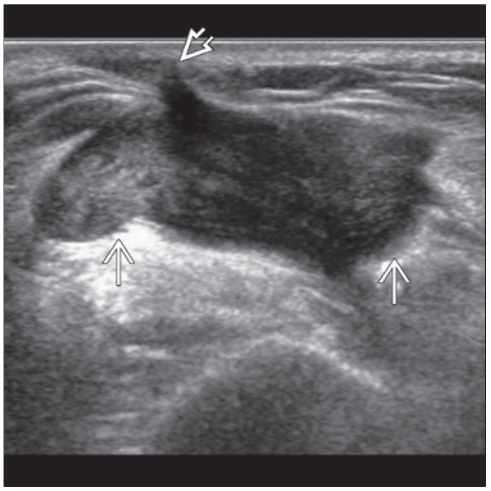
Metastases

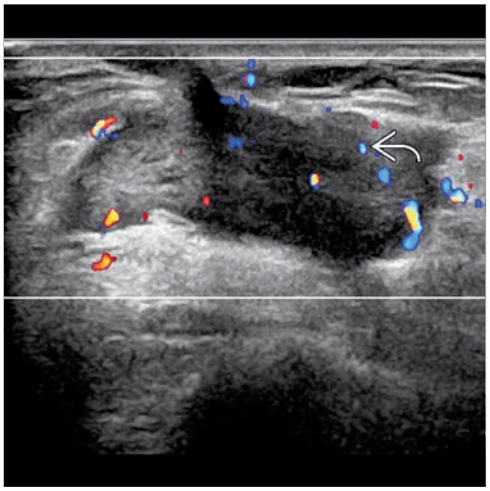




(Left) *Longitudinal ultrasound shows a well-defined, oval, subcutaneous metastasis in the anterior chest wall in a patient with lower limb melanoma. Melanoma metastatic lesions are typically markedly hypoechoic and associated with moderate posterior acoustic enhancement.* ***(Right)*** *Longitudinal power Doppler ultrasound of the same tumor shows moderate to high intrinsic vascularity with a chaotic, mainly peripheral vascular pattern.*

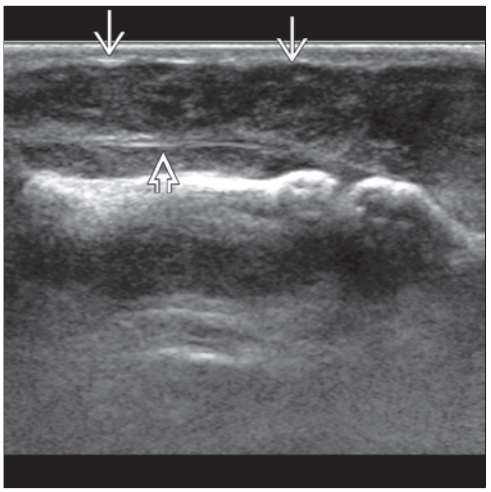
Fibroma

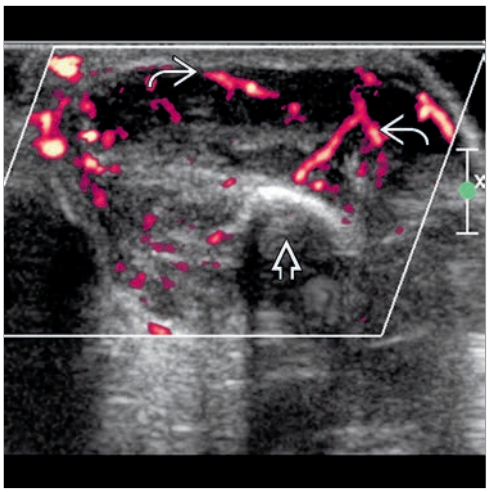




(Left) *Transverse ultrasound shows an irregular, hypoechoic, intramuscular soft tissue mass in the arm region due to fibromatosis. There is a band of tumor extending toward the skin.* ***(Right)*** *Transverse color Doppler ultrasound shows a mild degree of hyperemia within this area of fibromatosis. Note the characteristic hypoechoic appearance and irregular configuration of fibromatosis. Most fibromatosis tumors show minimal to mild hypervascularity on color Doppler imaging.*

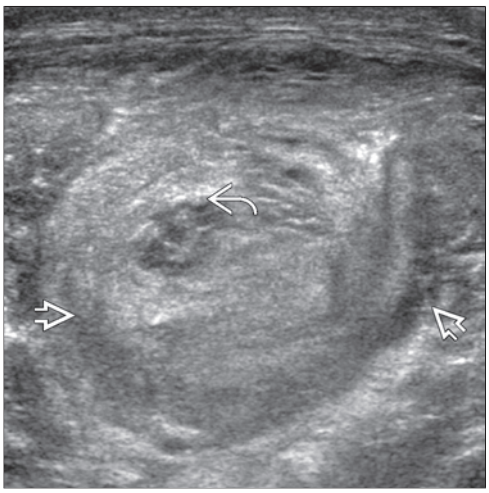
Giant Cell Tumor of Tendon Sheath



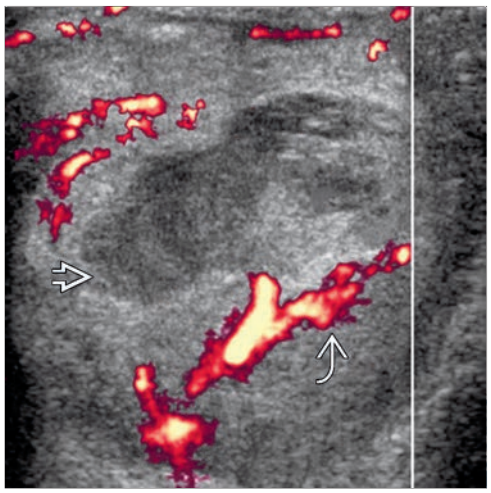


(Left) *Longitudinal ultrasound shows a hypoechoic soft tissue mass encasing the extensor tendon of the big toe. No intraarticular extension is present. Giant cell tumor of tendon sheath commonly occurs around tendons without a tendon sheath.* ***(Right)*** *Transverse power Doppler ultrasound of the same tumor shows moderate intratumoral vascularity. The mass is surrounding the phalanx of the big toe. Histology revealed an extraarticular giant cell tumor.*

Focal Myositis

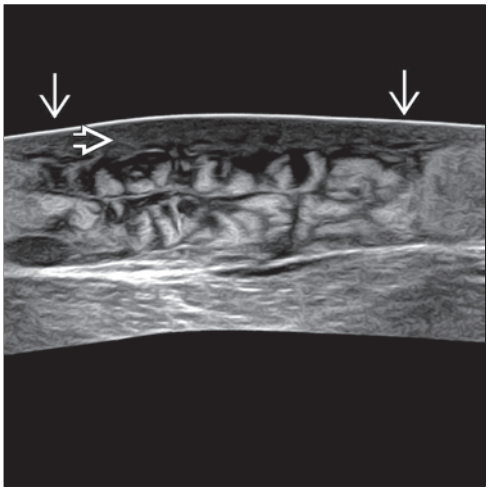


Focal Myositis

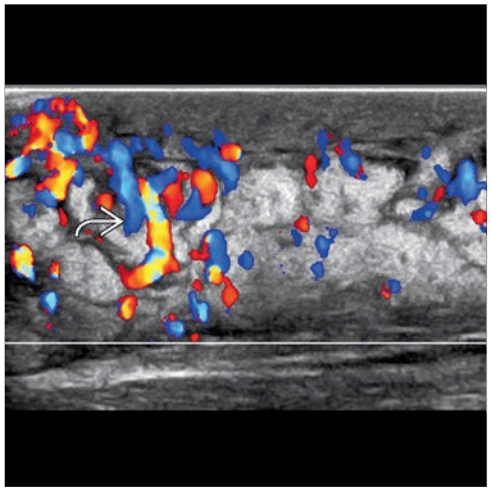


(Left) *Transverse ultrasound in an immunocompromised patient shows intense semimembranosus muscle edema with focal liquefaction due to infective myositis. There is moderate surrounding muscle and subcutaneous edema.* ***(Right)*** *Transverse power Doppler ultrasound of the same lesion shows moderate hyperemia of the infected area. There is a hypoechoic, avascular area centrally due to early abscess formation.*

Lymphoma

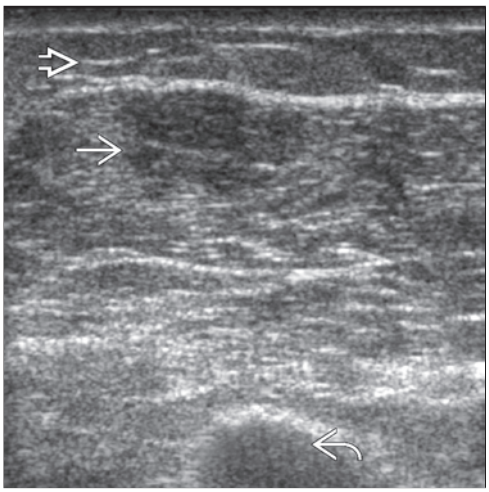


Lymphoma

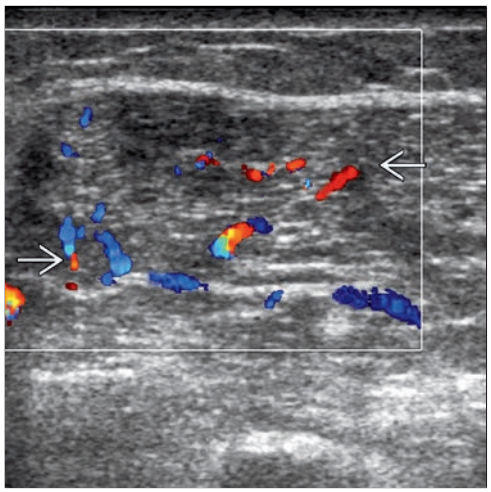


(Left) *Extended view-of-field ultrasound shows a poorly defined area of quite intense subcutaneous edema and swelling. No fluid collection is present, and there is no extension deep to the investing fascia. Moderate perilesional subcutaneous edema is present. The ultrasound diagnosis was atypical subcutaneous infection.* ***(Right)*** *Transverse color Doppler ultrasound shows intense intratumoral hypervascularity. Biopsy revealed peripheral T-cell lymphoma. This can masquerade as infection.*

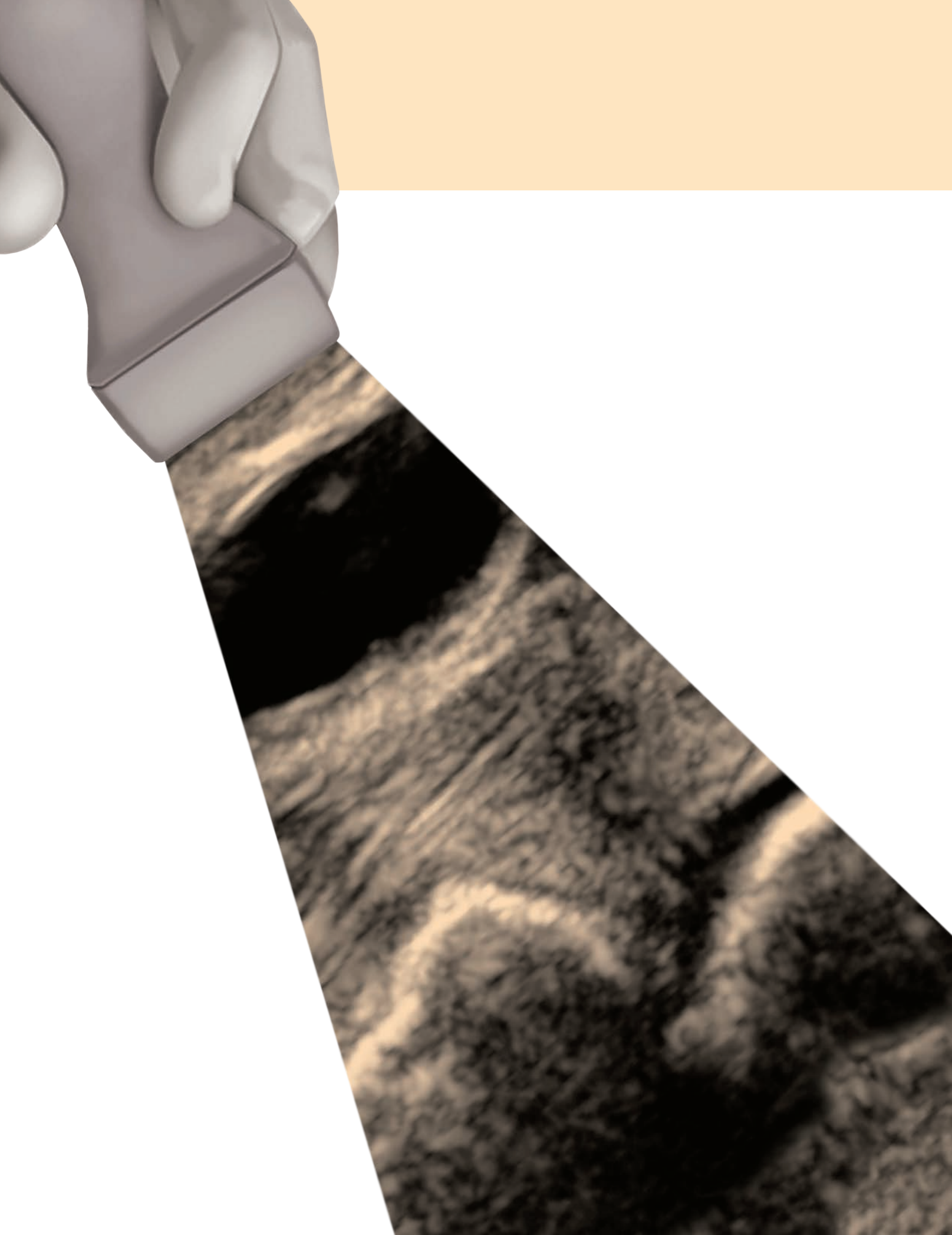
Diabetic Muscle Infarction



Diabetic Muscle Infarction



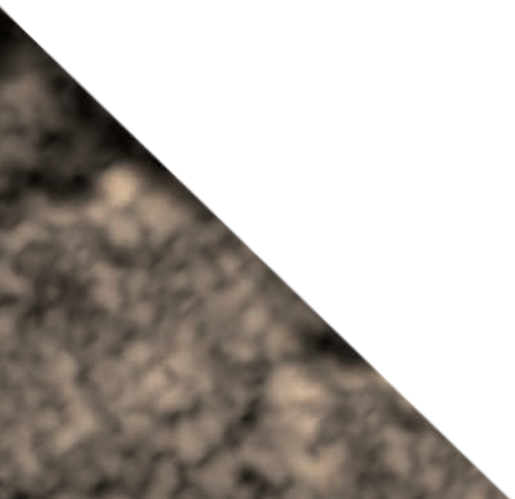
(Left) *Transverse ultrasound in a diabetic patient shows a well-defined hypoechoic area with broadly preserved background muscle architecture due to resolving biceps brachii muscle infarction. There is no subcutaneous edema. The humeral shaft is normal.* ***(Right)*** *Transverse color Doppler ultrasound of the same lesion shows moderate hyperemia around the infarcted hypoechoic area. Hyperemia occurs in the recovery stage of diabetic muscle infarction.*



SECTION 2

Tendon Abnormalities

Peritendinous Mass **III**-2-2
Tendon Hypoechogenicity **III**-2-6
Tendon Hyperechogenicity **III**-2-10
Tendon Swelling **III**-2-14



PERITENDINOUS MASS

DIFFERENTIAL DIAGNOSIS

Common
- Tenosynovitis
- Ganglion Cyst
- Giant Cell Tumor of Tendon Sheath
- Annular Pulley Thickening
- Extensor Retinaculum Thickening
- Nerve Sheath Tumor

Less Common
- Bursitis
- Gouty Tophus
- Synovial Sarcoma

ESSENTIAL INFORMATION

Key Differential Diagnosis Issues
- Consider whether affected tendon has tendon sheath
  - Only some tendons, notably those around wrist and ankle, have tendon sheaths
  - Some tendon areas, such as patellar and Achilles tendons, have incomplete tendon sheaths known as paratenon
  - Some tendon areas, such as extensor tendons of the fingers, do not have tendon sheath
  - Occurrence of tenosynovitis and giant cell tumor of tendon sheath is dependent on presence of tendon sheath or paratenon
- Relationship of mass to tendon ± tendon sheath is important
  - Dynamic assessment by tendon movement is helpful in this respect
- Color Doppler allows differentiation of hypoechoic synovial proliferation from hypoechoic tendon fluid

Helpful Clues for Common Diagnoses
- **Tenosynovitis**
  - Inflammation or infection of tendon sheath with secondary inflammation of tendon
  - Acute exudative tenosynovitis
    - Usually due to acute infection
    - Fluid with low-level echoes accumulates within tendon sheath
    - Echogenic speckles within fluid are due to aggregation of purulent debris
    - Real-time scanning with compression is useful to see movement of pus
    - Hyperemia around, rather than within, tendon sheath
    - Tendon sheath may rupture with spread of infection into peritendinous tissues
    - Tendon usually only mildly thickened ± indistinct margins
    - Ultrasound-guided aspiration is helpful to confirm infection and isolate organism
    - Determining extent of involvement is important for management; infection can spread along tendon sheath proximally and distally far away from initial swelling
  - Acute nonexudative tenosynovitis
    - Due to inflammation or infection
    - Synovial proliferation predominates over tendon sheath effusion
    - Hyperemia around, more than within, sheath
    - Fluid aspiration often unfruitful
  - Chronic active tenosynovitis
    - Due to inflammation or infection
    - Hyperemia within, rather than around, sheath
  - Chronic inactive tenosynovitis
    - Mild thickening of tendon sheath with clear tendon sheath effusion
    - ± tendon sheath adhesions with entrapped, noncompressible fluid
- **Ganglion Cyst**
  - Filled with gelatinous-type material of variable consistency
  - Anechoic, cystic-like structure closely related to joint
    - Noncompressible
    - Common sites are wrists, base of fingers, and tarsus
  - May be irregular in outline
  - Can originate from tendon sheath: No extension to adjacent joint
  - Usually originates from joint and extends to peritendinous location
    - Usually points toward or is closely related to particular joint
    - Try to identify joint of origin since this has treatment implications
    - Usually neck or stalk of ganglion cyst cannot be actually followed into joint
  - ± "comet tail" artifacts within cyst
  - ± leakage/rupture/hemorrhage of cyst
- **Giant Cell Tumor of Tendon Sheath**
  - Composed of multinucleated cells and fibroblast-like cells that may have hemosiderin deposits
    - Pathologically, giant cell tumors of tendon sheath are identical to pigmented villonodular synovitis
  - Common in hand, wrist, and foot
    - May also occur around elbow or knee or anywhere tendon sheaths exist
    - Preferentially involves first 3 fingers and first 2 toes
  - All giant cell tumors contact tendon to some degree
    - Usually tendon sheath is only partially encased
    - Complete encasement is less common
    - Tendon movement is not affected since tumor expands on outer margin of tendon sheath
  - Hypoechoic tumor, which may be irregular, fusiform, or rounded in outline
    - Tends to extend along long axis of tendon sheath
    - Posterior acoustic enhancement, cystic areas, or calcification are not seen
  - Usually moderately vascular; infrequently may have no demonstrable flow on color Doppler imaging
  - ± bone erosions
  - May be multifocal
  - Recurrence rate is high
- **Annular Pulley Thickening**
  - Pulleys are series of fibrous slings that maintain close proximity between flexor tendons and fingers during finger flexion
  - Pulley thickening usually affects A1 pulley, which is located at metacarpophalangeal joint level
    - Leads to restriction of flexor tendon movement known as "trigger finger"
  - Normal pulley seen as thin, hypoechoic band looping over tendon from bony attachment
    - Normally ~ 0.5 mm thick at area most distant from bone
  - In "trigger finger," A1 pulley thickens to 1-2 mm
    - ± hyperemia of pulley
    - ± tendinosis or tenosynovitis of flexor tendons

- Dynamic imaging allows depiction of flexor tendon movement restriction
  - Superficialis tendon movement restricted more than profundus tendon

- **Extensor Retinaculum Thickening**
  - Most common at 1st extensor compartment of wrist (de Quervain disease, baby wrist)
  - Retinaculum and flexor pulleys are histologically identical with 3-layered structure
    - Superficial layer: Loose connective tissue (nutritional layer)
    - Intermediate layer: Fibrous tissue (mechanical layer), contains estrogen receptors
    - Deep layer: Flattened fibroblasts, cells that secrete hyaluronic acid ± areas of chondroid metaplasia (gliding layer)
  - Associated with post-partum status ("baby wrist"), aromatase inhibitors, tamoxifen ingestion, and diabetes
  - Thickening (1-1.5 mm) of extensor retinaculum, normal < 0.5 mm thick
    - ± variable peritendinitis with hyperemia and edema of adjacent tissues
    - ± tendon sheath effusion
  - Associated with variable tendinosis of abductor pollicis longus and extensor pollicis brevis
    - Leads to restriction of tendon movement
    - Demonstrable on real-time ultrasound

- **Nerve Sheath Tumor**
  - Often occur in proximity to tendons particularly at wrist and ankle
  - Arise along course of subcutaneous nerve or cutaneous nerve
  - Fusiform-shaped, hypoechoic with posterior acoustic enhancement and moderate vascularity in continuity with a nerve
    - ± thickening of entering or exiting parent nerve (very common)
    - ± areas of myxoid accumulation (very common)
    - ± areas of hemorrhage or calcification (much less common)
    - If tumors arise from small peripheral nerves, entering or exiting nerve may not be visible
    - Cannot differentiate between schwannoma and neurofibroma based on ultrasound appearance

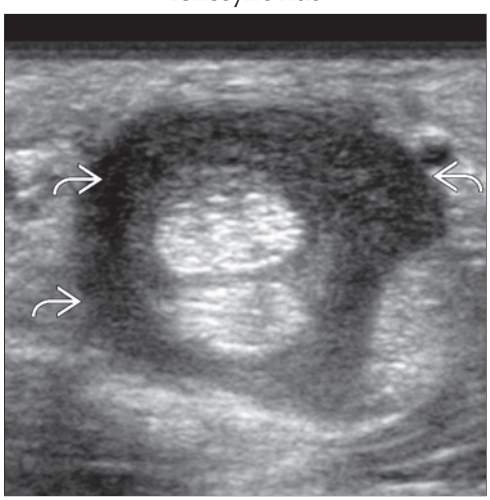
Helpful Clues for Less Common Diagnoses

- **Bursitis**
  - Chronic frictional trauma or overuse
  - Bursa usually located alongside tendons
    - Distended hypoechoic bursa
    - Variably distended with echogenic fluid
    - Thickened wall ± internal septations ± hemorrhage
    - Inflammation of soft tissue/subcutaneous tissue with hyperemia
    - Acute: Hyperemia of peribursal soft tissue on color Doppler imaging
    - Chronic: ± calcification and may mimic mass
    - Typical site is pes anserinus bursa: Distended bursa indented by 3 tendons looks like goose's foot (hence anserine)

- **Gouty Tophus**
  - Crystal deposition in proximity of tendon is common
    - Soft or hard tophi depending on level of crystal deposition
    - Crystal aggregates → "comet tail" artifacts
  - Usually large, irregular, heterogeneous, hypoechoic mass with calcified foci and hyperemia
  - Calcifications within tendon can occur in chronic gout
  - Multiple joint involvement
  - Typical clinical history and raised plasma urate

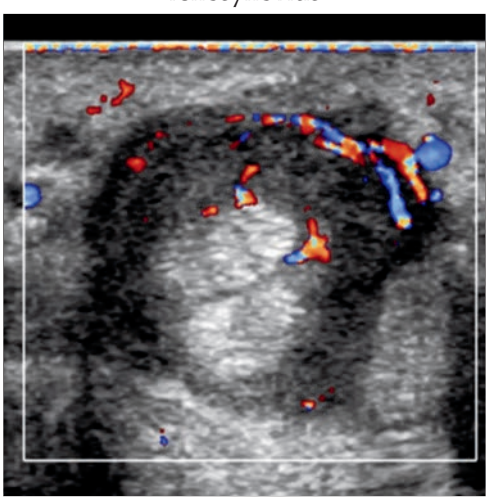
- **Synovial Sarcoma**
  - Often occur in proximity to tendons particularly at wrist and hand
  - Large, heterogeneous, hypoechoic mass with well-defined margin
  - Usually located in paraarticular region, sometimes surrounding tendon
  - Usually hypervascular
  - Posterior acoustic enhancement, cystic areas, or calcification may be seen

Tenosynovitis



Transverse ultrasound of flexor digitorum tendon shows severe synovial thickening surrounding the mildly swollen tendons, suggestive of chronic tenosynovitis.

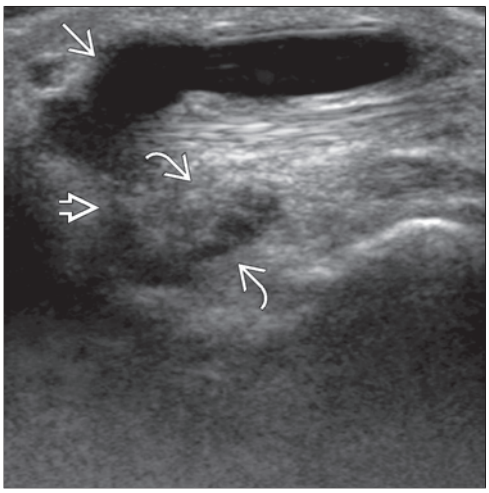
Tenosynovitis



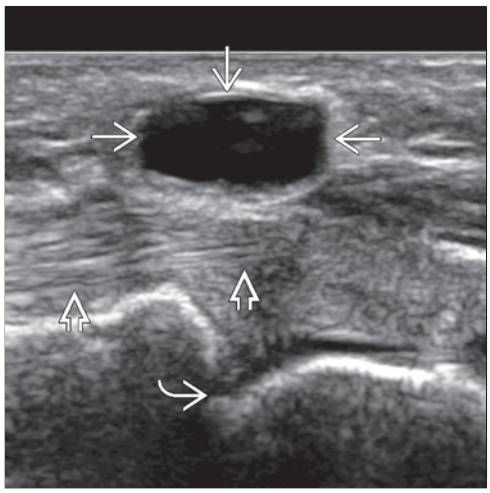
Transverse color Doppler ultrasound at the corresponding level as previous image shows moderate peritendinous hyperemia, suggestive of chronic active tenosynovitis.

PERITENDINOUS MASS

Ganglion Cyst

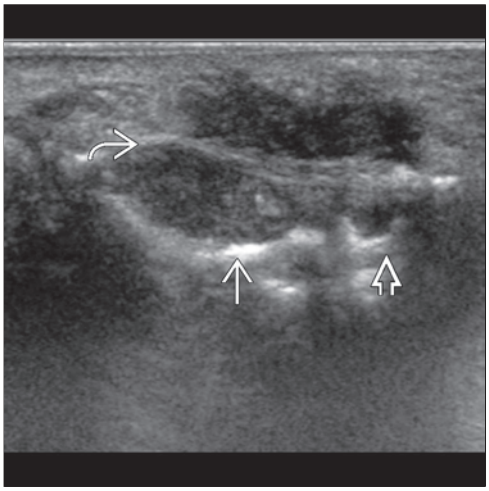


Ganglion Cyst

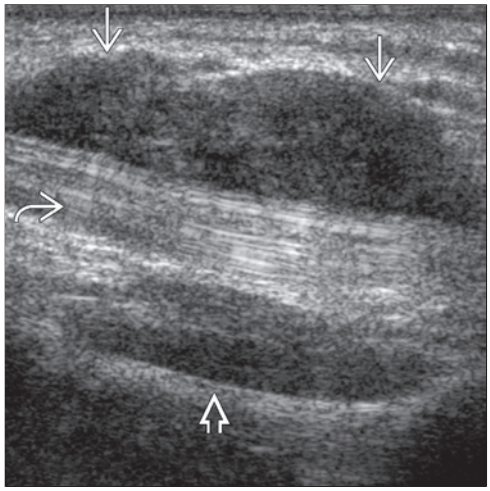


(Left) *Longitudinal ultrasound shows an elongated ganglion on the radiovolar aspect of the wrist. The stalk of the ganglion extends deeply to lie between the radioscaphocapitate and radiolunotriquetral ligaments.* ***(Right)*** *Longitudinal ultrasound of the same patient shows a subcutaneous unilocular ganglion located dorsal to the extensor tendon of the middle finger at the level of the metacarpophalangeal joint.*

Giant Cell Tumor of Tendon Sheath

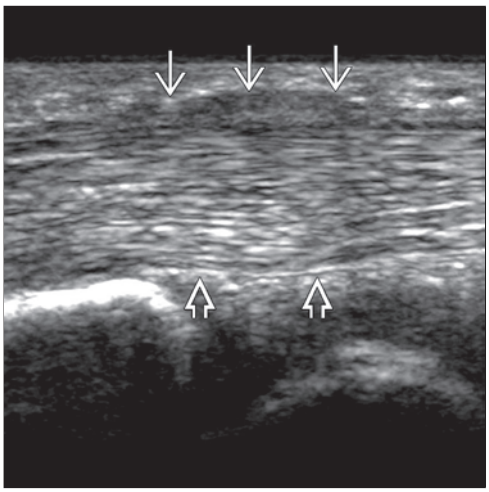


Giant Cell Tumor of Tendon Sheath

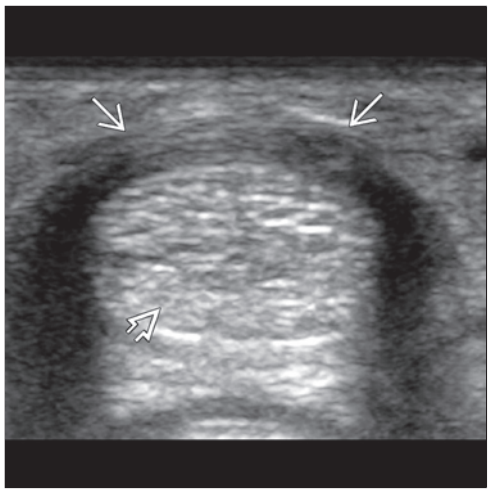


(Left) *Longitudinal ultrasound of the 5th toe shows a large, hypoechoic, solid soft tissue mass overlying the proximal and distal phalanges and encasing the extensor digitorum tendon. Histology confirmed giant cell tumor.* ***(Right)*** *Longitudinal ultrasound of the finger shows a large, solid soft tissue mass with no calcification overlying the metacarpal bone and encasing the flexor digitorum tendon. Histology confirmed giant cell tumor.*

Annular Pulley Thickening

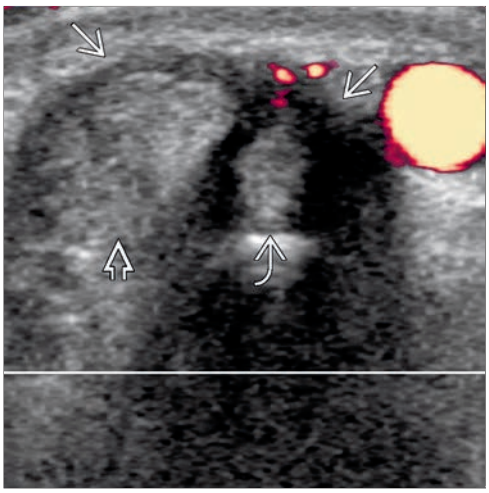


Annular Pulley Thickening

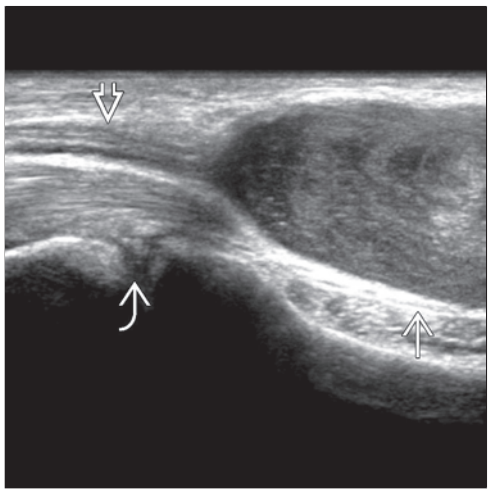


(Left) *Longitudinal ultrasound at the metacarpophalangeal joint level shows severe thickening of the A1 pulley. The underlying flexor tendon is moderately swollen and showed restriction of passive movement on dynamic testing.* ***(Right)*** *Transverse ultrasound shows a thickened A1 pulley overlying the flexor tendons of the middle finger in a patient with "trigger finger."*

Extensor Retinaculum Thickening

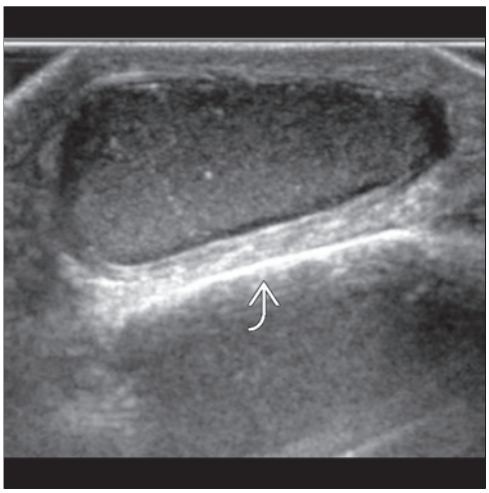


Nerve Sheath Tumor

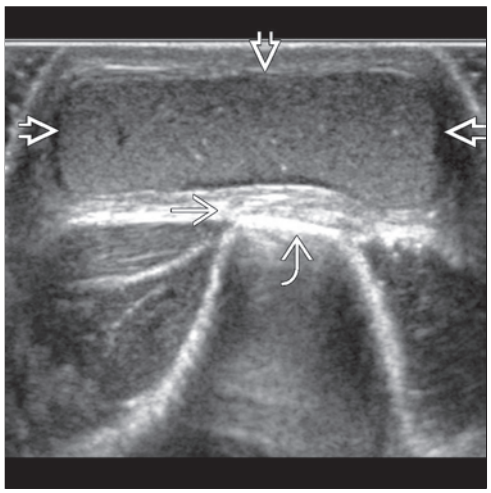


(Left) *Transverse color Doppler ultrasound shows mild thickening and minimal hyperemia of 1st extensor compartment retinaculum. There is severe abductor pollicis longus tendinosis with a normal extensor pollicis brevis tendon.* ***(Right)*** *Longitudinal ultrasound of the wrist shows a mass arising from the median nerve proximal to the carpal tunnel. The median nerve is slightly thickened. Note the radiocarpal articulation. Histology confirmed a schwannoma.*

Bursitis

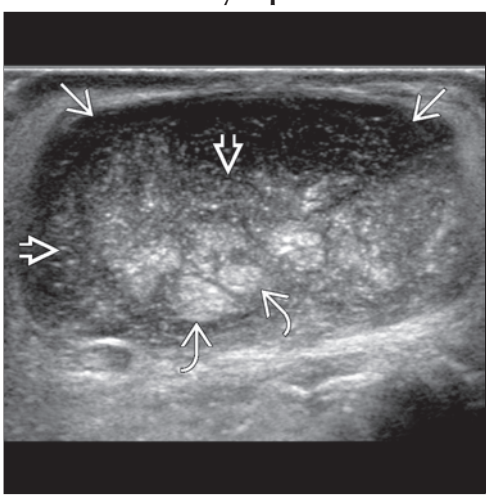


Bursitis

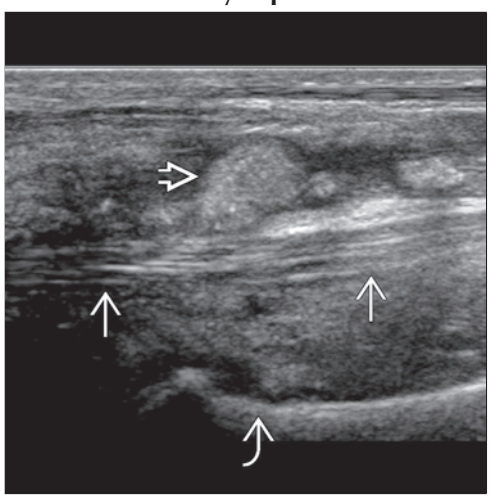


(Left) *Longitudinal oblique ultrasound shows a well-defined elbow mass located between the olecranon and the skin, compatible with olecranon bursitis. The bursa is distended by fluid with low-level echoes suggestive of high proteinaceous or hemorrhagic content.* ***(Right)*** *Transverse ultrasound of the same mass lying superficial to the triceps tendon and olecranon.*

Gouty Tophus



Gouty Tophus



(Left) *Transverse ultrasound shows very severe gouty tenosynovitis of the flexor tendons of the hand. The tendon sheath is severely distended with finely echogenic fluid ("urate sand"), which surrounds the flexor tendons.* ***(Right)*** *Longitudinal ultrasound of the hand shows severe gouty tenosynovitis at the metacarpal level. The flexor digitorum tendon sheath is distended with fluid and large crystal aggregates, which surround the tendon.*

TENDON HYPOECHOGENICITY

DIFFERENTIAL DIAGNOSIS

Common
- Anisotropy
- Tendinosis
- Tendon Tear

Less Common
- Intratendinous Vessel
- Xanthomatosis
- Amyloidosis

ESSENTIAL INFORMATION

Key Differential Diagnosis Issues
- Be familiar with normal appearances of tendon and insertion before commenting on abnormality
- Changing position of limb can optimize tendon visibility
  - Particularly important when evaluating shoulder
- Always confirm abnormality on orthogonal view
- Dynamic assessment to view tendon movement is useful
- Color Doppler is useful to assess tendon vascularity and distinguish between tears and vascular channels
  - Stretching tendon may compress vascularity
  - Try to assess vascularity when tendon is relaxed
  - Normal tendons show no internal vascularity on color Doppler imaging
- Some tendons more prone to neovascularization than others
  - Achilles, posterior tibialis, and patellar tendons and tendons originating in common extensor tendon are prone to vascular ingrowth with disease
  - Rotator cuff tendons rarely show vascular ingrowth

Helpful Clues for Common Diagnoses
- **Anisotropy**
  - Reflectivity of normal tendon, nerve, and muscle is dependent on angle of transducer
  - Tendon best seen when incident beam is perpendicular to tendon
  - Any alteration from perpendicular irrespective of direction can lead to loss of reflectivity (anisotropy)
    - Tendinosis and tears also lead to loss of echogenicity, so ensure that ultrasound beam is maintained at right angles to tendon
    - Tilt probe at different angles to confirm whether abnormality is real or not
    - Dynamic scan with tendon movement can also help to confirm abnormality
- **Tendinosis**
  - Failed wound healing cascade after microtear sustained either during specific injury or repetitive microtrauma due to overuse
  - Pathologically represents degenerative process of tendons
    - Hypercellularity and irregular vascular ingrowth
    - Collagen fiber disorganization and thinning
    - ↑ interfibrillar glycosaminoglycan deposition
    - Inflammatory cell infiltrate not a feature of tendinosis
  - Tendons more prone to tendinosis in upper limb
    - Supraspinatus, infraspinatus, subscapularis, and long head of biceps
    - Common tendon extensor origin, extensor carpi ulnaris, abductor pollicis longus, and extensor pollicis brevis
  - Tendons more prone to tendinosis in lower limb
    - Hamstrings at ischial tuberosity attachment; gluteus minimus and medius at greater trochanteric insertion
    - Quadriceps, patellar, Achilles, peroneal, and posterior tibialis tendons
  - Seen on ultrasound as tendon thickening, hypoechogenicity, and loss of normal fibrillar pattern ± focal hyperemia
  - May be focal or diffuse
  - Tendon thickening
    - Tendon cross-sectional area larger than expected (compare with asymptomatic side if normal in appearance)
  - Loss of normal fibrillar pattern and hypoechogenicity
    - Due to proteoglycan matrix deposition between tendon fibrils
  - Hyperemia
    - Vessels not present within normal tendons
    - Level of hyperemia is proportional to level of tendinosis disease activity
    - May be related to disease progression or repair; reduction in hyperemia correlates with decrease in symptoms
    - Subjectively graded as mild, moderate, or severe
    - For Achilles tendon: Mild is ≤ 2 vessel ingrowth, moderate is 3-4 vessel ingrowth, and severe is ≥ 5 vessel ingrowth
  - Secondary signs of tendinosis
    - More common in severe tendinosis
    - Tendon sheath effusion (if tendon sheath present)
    - Adjacent bursitis (Achilles, common extensor)
    - Cortical irregularity ± hyperostosis at insertional area
    - Intrinsic tendon calcification
    - Variable degree of peritendinitis
- **Tendon Tear**
  - Ultrasound accurately detects macroscopic tendon tears
  - May occur at insertion (avulsive type), at tendon surface, or within tendon substance (intrasubstance)
  - Tendon tears are strongly associated with tendinosis
    - Likelihood of tendon tear increases with increasing severity of tendinosis
    - Tendon tears occur in those areas where tendinosis occurs
    - Tears are uncommon in normal tendons
  - Tears tend to happen at specific sites for each tendon
    - Supraspinatus is most commonly torn tendon (avulsive-type tear anterior fibers)
    - Achilles tendon tears occur at junction of proximal and middle 1/3 of tendon
    - Common extensor tendon tears are intrasubstance or deep avulsive-type tears
    - Biceps tendon tears are often longitudinal tears at proximal aspect of bicipital groove
    - Peroneal & posterior tibialis tendons typically located at retromalleolar & inframalleolar regions
  - Partial thickness tear
    - Focal discontinuity of tendon not involving all tendon fibers
    - Sharp linear hypoechoic defect within area of tendinosis

- Lack of complete tendon retraction is the most important feature to distinguish partial from complete tear
- Tears usually on background of tendinosis
- Occur with moderate to severe tendinosis
- Uncommon to see tears in normal healthy tendons
- Should not be confused with dilated vascular channels within hyperemic tendon; color Doppler imaging is helpful
- Should not be confused with proteoglycan accumulation; focal hypoechoic area with bulging tendon contour
- ± dystrophic calcification, adjacent bursitis, reactive bone changes

○ Full thickness tear
- Tendon discontinuity with anechoic or hypoechoic area
- Retraction gap may be filled with echogenic blood, making tear less conspicuous
- Often swollen tendon ends, especially in small finger tendons
- Collapsed synovial sheath may be mistaken for attenuated tendon (applies to smaller tendons, e.g., finger flexors and biceps tendon)
- Proximal and distal stumps may show severe tendinosis with dystrophic calcification
- ± tendon indentation and contour deformity
- ± peritendinous or bursal fluid

○ Peritendinitis
- Edema and hyperemia of peritendinous tissues
- Important feature of tendinosis to note as it will respond to anti-inflammatory medication

Helpful Clues for Less Common Diagnoses

• **Intratendinous Vessel**
○ Should not be confused with partial intrasubstance tear
○ Dilated vascular channels within hyperemic tendon due to tendinosis
○ Vessels normally not present within tendons
○ Level of hyperemia is proportional to level of tendinosis disease activity
○ May be related to disease progression or repair
○ Color Doppler imaging is diagnostic

• **Xanthomatosis**
○ Tendon xanthomas are manifestation of familial hyperlipidemia
- Xanthomas are composed of lipid-filled foamy histiocytes, extracellular cholesterol ester, and giant cells

○ Appear most commonly as fusiform hypoechoic enlargement of tendon
- ± discrete hypoechoic areas (due to more concentrated cholesterol deposition)

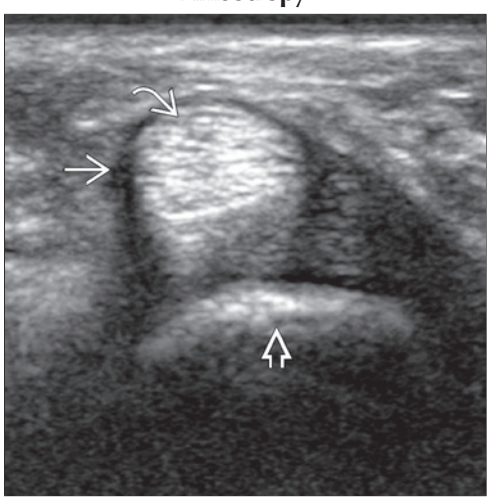
○ Achilles tendon > patellar tendon > extensor tendons of hands and feet
- In the Achilles tendon, discrete small calcific foci may also be seen along length of tendon

○ Xanthoma may regress with lipid-lowering treatment
○ Useful marker given its specific relationship to atherosclerosis
- Increased intima-media thickness and plaques

○ Xanthoma may be difficult to distinguish from tendinosis; helpful, though not very specific, distinguishing ultrasound features of xanthomatosis are
- Similar ultrasound appearances bilaterally
- Tends to show more discrete areas of hypoechogenicity
- Tends to be less hyperemic on color Doppler imaging
- Occurrence of scattered small intratendinous calcifications (~ 20%)

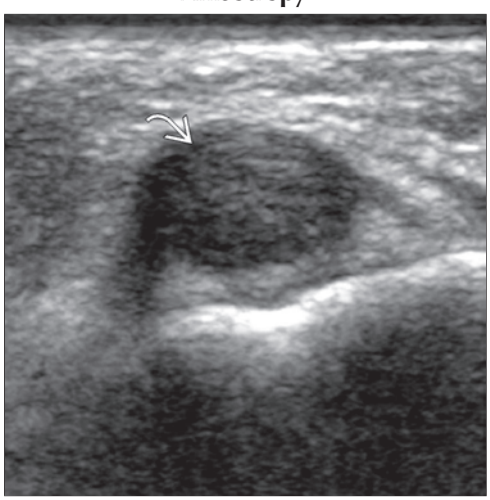
• **Amyloidosis**
○ Inherited or secondary (chronic renal failure, multiple myeloma, chronic inflammation)
○ Overproduction of fibrous protein aggregates which become insoluble and deposit in tissues
○ Heart, lungs, kidneys, spleen, gastrointestinal tract, nerves, and tendons
○ → tendon thickening and hypoechogenicity
- Supraspinatus tendon > biceps tendon > hand and wrist tendon
- ± nodular tendon sheath or bursal thickening
- Predisposes to tendon tears

Anisotropy



Transverse ultrasound of the middle finger shows normal echogenicity of flexor tendons at the level of the A1 pulley and metacarpal head.

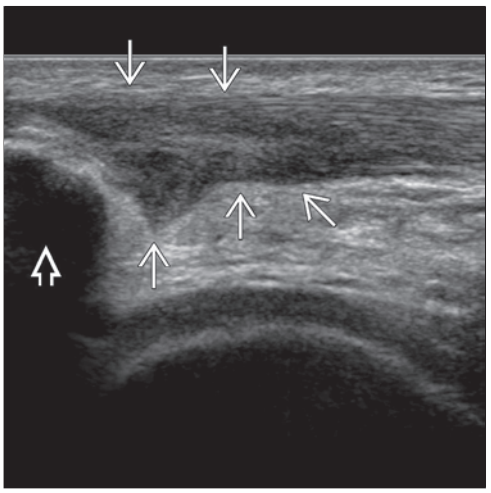
Anisotropy



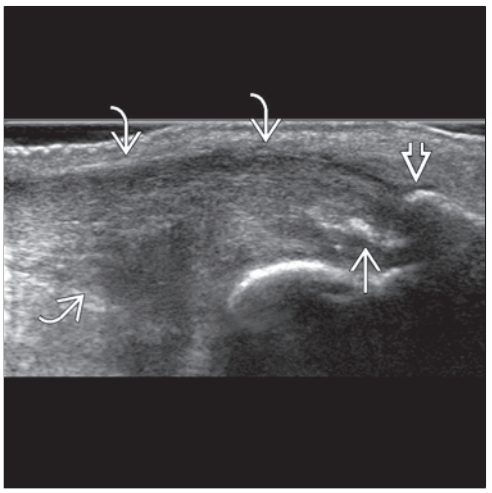
Transverse ultrasound at the same level shows that tendon echogenicity changes from hyperechoic to hypoechoic when the transducer is not aligned at a right angle to the tendon.

TENDON HYPOECHOGENICITY

Tendinosis

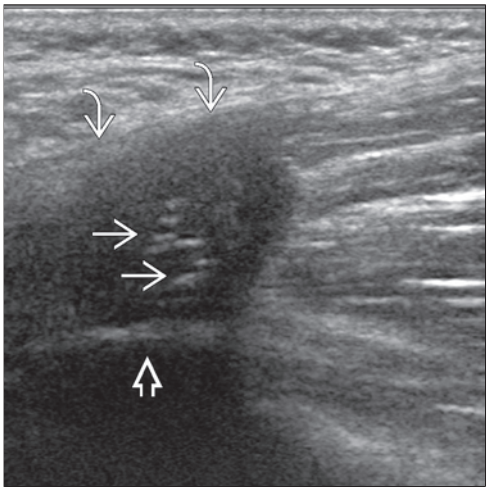


Tendinosis

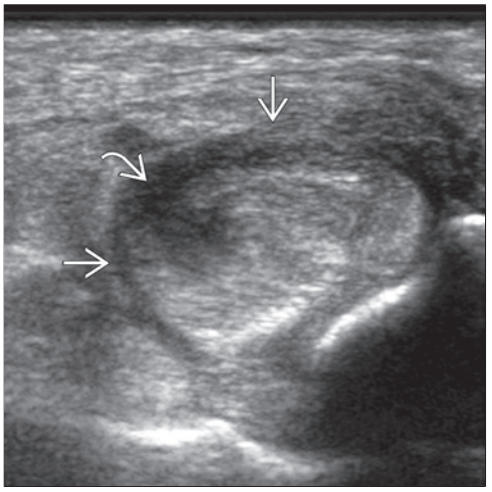


(Left) *Longitudinal ultrasound of patellar tendon shows a severely thickened, hypoechoic tendon near the inferior pole of patella, with more severe involvement of deeper fibers, consistent with severe patellar tendinosis.* ***(Right)*** *Longitudinal ultrasound of the distal portion of the Achilles tendon shows diffuse severe tendon thickening with hypoechogenicity. Small foci of dystrophic calcification above a prominent calcaneal spur are also seen.*

Tendinosis

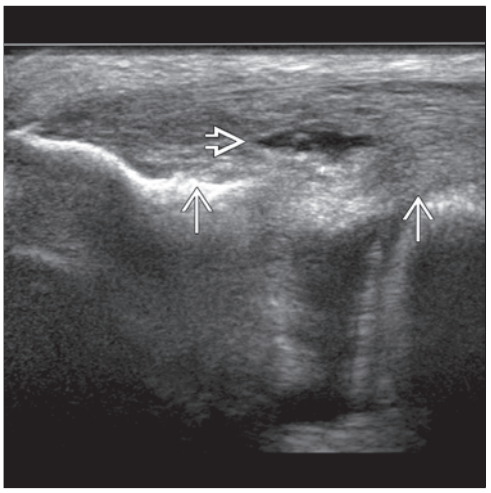


Tendinosis

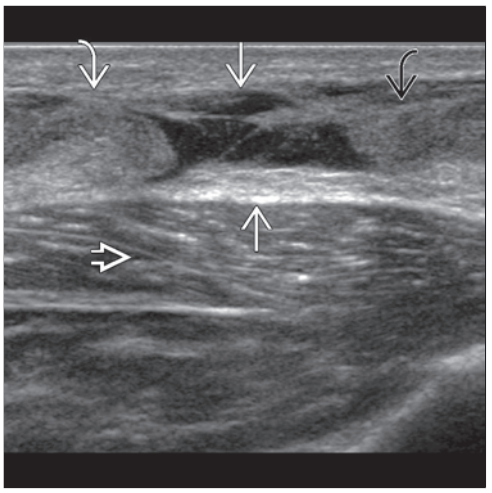


(Left) *Longitudinal ultrasound of the adductor longus tendon shows multiple foci of calcification close to the adductor longus origin at the pubic ramus. The tendon is moderately swollen and hypoechoic, consistent with tendinosis.* ***(Right)*** *Transverse ultrasound of the retromalleolar tibialis posterior tendon shows severe tendinosis with a thickened heterogeneous tendon. The small hypoechoic area with an ill-defined margin within the tendon is consistent with localized proteoglycan accumulation.*

Tendon Tear



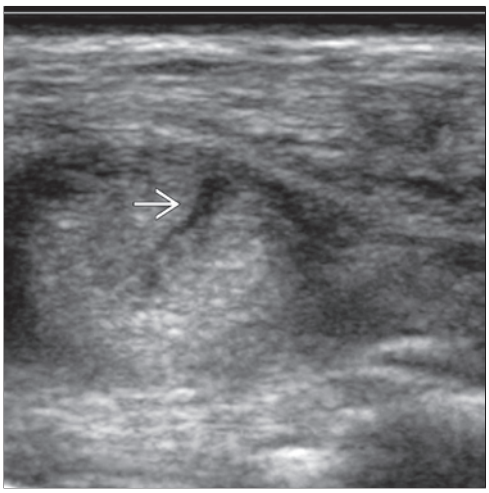
Tendon Tear



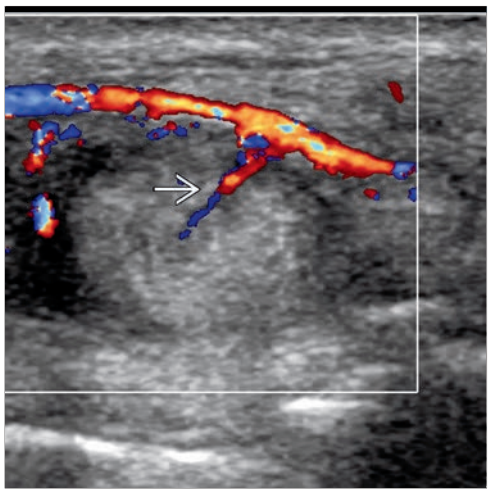
(Left) *Longitudinal ultrasound shows tendinosis and fusiform thickening of the proximal Achilles tendon. A small longitudinal intrasubstance partial tear is located within the central portion of the tendon.* ***(Right)*** *Longitudinal ultrasound of the Achilles tendon shows a complete tear at the proximal third of the tendon. The proximal and distal tendon ends are retracted. The soleus muscle deep to the tear is normal.*

TENDON HYPOECHOGENICITY

Intratendinous Vessel

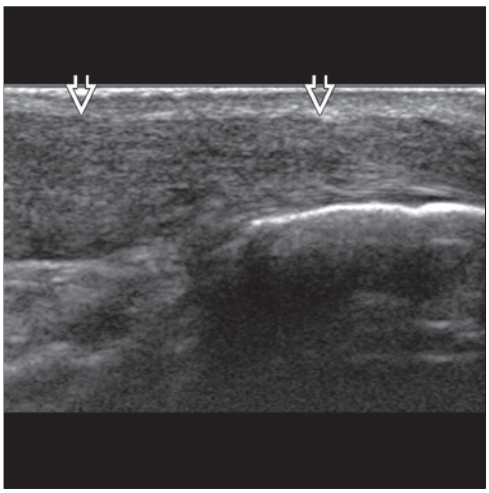


Intratendinous Vessel

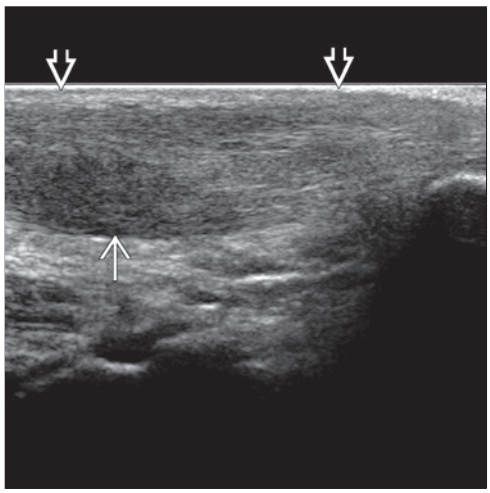


(Left) *Transverse ultrasound of the posterior tibialis tendon shows a linear, discrete, hypoechoic line extending from the surface to the center of the tendon, suspicious of a partial thickness tear.* ***(Right)*** *Transverse color Doppler ultrasound of the corresponding region shows that the linear, discrete, hypoechoic line represents a vascular channel. Always check any suspected partial tears with color Doppler ultrasound.*

Xanthomatosis

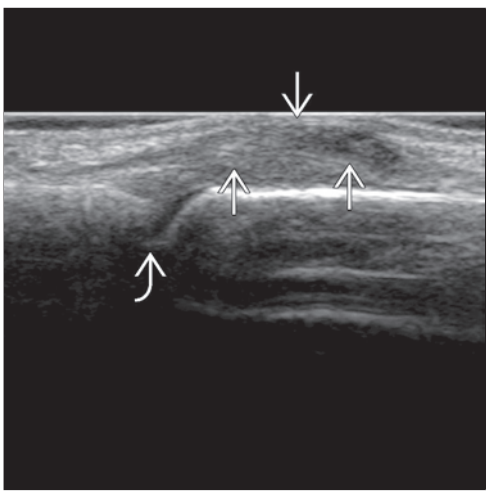


Xanthomatosis

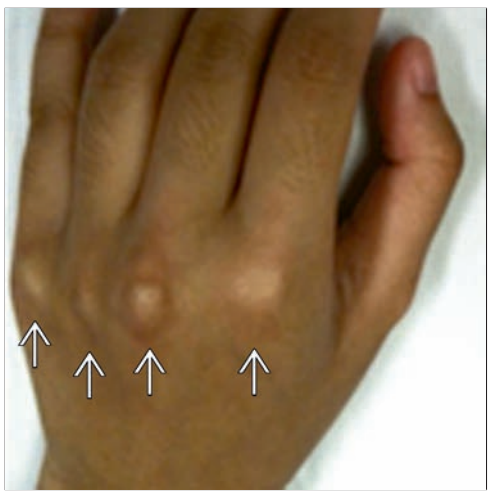


(Left) *Longitudinal ultrasound of distal 1/3 of the Achilles tendon in a patient with familial hypercholesterolemia shows moderate severity diffuse tendon thickening and hypoechogenicity without any discrete xanthoma.* ***(Right)*** *Longitudinal ultrasound of the Achilles tendon in a patient with familial hypercholesterolemia shows that the tendon is diffusely thickened with a more focal hypoechoic area on the deeper aspect of the tendon due to a localized cholesterol deposition (xanthoma).*

Xanthomatosis



Xanthomatosis



(Left) *Longitudinal ultrasound in the same patient as previous image shows moderate hypoechoic thickening of the extensor tendon hood over the metacarpophalangeal joint due to a tendon xanthoma.* ***(Right)*** *Clinical photo of the same patient shows xanthomas overlying the metacarpophalangeal joints.*

TENDON HYPERECHOGENICITY

DIFFERENTIAL DIAGNOSIS

Common
- Calcific Tendinitis
- Calcification Within Tendinosis
- Gout

Less Common
- Tendon Tear
- Avulsion Injury of Tendon
- Accessory Ossicle
- Suture Material Within Tendon
- Foreign Body Within Tendon

ESSENTIAL INFORMATION

Key Differential Diagnosis Issues
- Normal tendons are moderately echogenic with a distinct fibrillar pattern
- Areas of tendon hyperechogenicity are usually due to calcification or crystal deposition within tendon substance
  - Alternatively gas, blood, or suture
- Ultrasound is more sensitive than radiography or MR at detecting calcification or crystal deposition within tendon
- Calcification or crystal deposition varies from small, hyperechoic foci with "comet tail" artifacts to large, confluent areas of dense hyperechogenicity with dense, acoustic shadowing
- Large areas of calcification or crystal deposition within tendon may limit assessment of tendon tears

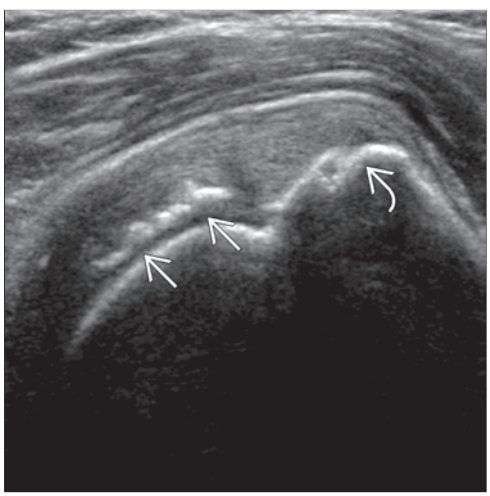
Helpful Clues for Common Diagnoses
- **Calcific Tendinitis**
  - Due to deposition of hydroxyapatite crystal within tendon substance
  - Leads to severe pain and restriction of movement
    - Can affect any tendon, though some tendons are particularly prone to calcific tendinitis
    - Age: 40-60 years
    - Formative, resting, and resorptive phases
  - Tendons around shoulder are most commonly affected
    - Supraspinatus > infraspinatus > subscapularis tendon
  - Other less commonly affected tendons are
    - Flexor carpi ulnaris tendon
    - Hamstring tendons at ischial tuberosity
    - Rectus femoris tendon near iliac attachment
    - Adductor tendons near pelvic attachment
    - Gluteus medius and minimus tendons at greater trochanteric insertion
    - Quadriceps tendon
    - Flexor hallucis longus tendon
  - Focal hyperechoic area of varying size and shape
    - Arch-shaped (most common)
    - Punctuate or fragmented
    - Nodular
    - Cystic type (uncommon)
  - ± acoustic shadowing depending on size
  - ± associated tendinosis (mild, moderate, or severe)
  - ± tendon tear
  - ± intraarticular hydroxyapatite crystal deposition
  - ± pericalcific color flow on Doppler imaging
    - Grade 0 = no flow
    - Grade 1 = weak spot of color flow signal
    - Grade 2 = few linear color flow signals
    - Grade 3 = many linear color flow signals
  - Color Doppler may be able to distinguish between formative and resorptive phases of calcific tendinitis
    - If no pericalcific color flow visible, this suggests formative phase, and aspiration may be indicated
    - If pericalcific color flow visible, this suggests resorptive phase, and conservative treatment may be indicated with better clinical outcome
  - Several tendons may be affected simultaneously
  - Contralateral side is also frequently affected, even though asymptomatic
  - Treatment includes analgesia and local heat (self-limiting condition)
    - ± ultrasound-guided needling
    - ± aspiration lavage and aspiration
    - ± ultrasound-guided steroid or long-acting local anesthetic
    - Extracorporeal shock-wave therapy (ESWT)
    - Acetic acid iontophoresis; applying direct current to drive ions through tissues; injection without a needle
- **Calcification Within Tendinosis**
  - Usually only found within Achilles tendon and, to lesser degree, posterior tibialis and patellar tendons
    - Site-specificity allows easy differentiation from calcific tendinitis, which mainly affects rotator cuff tendons
  - Affects tendons close to insertional area
    - Posterosuperior aspect calcaneus of Achilles tendon
    - Medioinferior navicular bone for posterior tibialis tendon
  - Usually associated with background tendinosis
  - Discrete areas of calcification within tendon from few mm to few cm
    - Mature, solid-looking, with well-defined margins, and little, if any, associated pain or tenderness
    - Strong propensity to ossify
    - Not possible to aspirate, unlike calcific tendinitis
  - Strong posterior acoustic shadowing
  - Usually associated with reactive bony changes at insertional area
    - Cortical irregularity
    - Cortical surface fragmentation
    - Cortical hyperostosis and spur formation
  - May occur in asymptomatic subjects with no other ultrasound features of tendinosis
    - Particularly in Achilles tendon
- **Gout**
  - Crystal deposition within tendon substance or alongside tendon
  - Usually associated with gouty tophi within tendon sheath and tendon sheath effusion
  - Most crystal deposition tends to be around tendons, ligaments, and joints
    - Intratendinous deposition is more common feature of chronic gouty arthropathy
    - Rare feature of calcium pyrophosphate crystal deposition
  - Focal tendon thickening
    - Loss of normal fibrillar pattern
  - Intratendinous crystal aggregates seen as "comet tail" artifacts within tendon
    - ± posterior acoustic shadowing depending on degree of crystal deposition
    - ± mild peritendinous or intratendinous hyperemia

- Normally affects tendons of smaller joints, including wrist/hand or ankle/foot
  - Less common in larger tendons
  - Typical clinical history and raised plasma urate
- Usually associated with gouty tophi
  - Extraarticular gouty tophi depending on level of crystal deposition
  - Usually large, irregular, heterogeneous, hypoechoic mass with calcified foci and hyperemia
  - Soft tophi: Hyperechoic with no acoustic shadowing
  - Hard tophi: Hyperechoic with intense acoustic shadowing
  - Quite well-defined irregular margins with variable hypoechoic halo (wet clump of sugar)
  - Multiple grouped tophi common
- Usually associated with gouty arthropathy
  - Variable appearance of joint fluid
  - Hyperechoic aggregates in synovial fluid
  - Fine punctuated echogenicity (urate sand) or large echogenic aggregates (snowstorm appearance)

Helpful Clues for Less Common Diagnoses

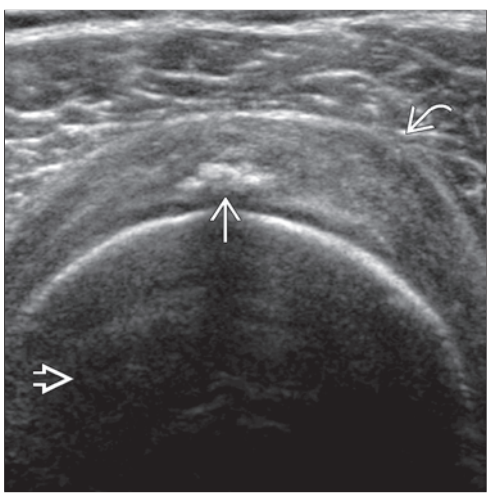
- **Tendon Tear**
  - Often associated with hemorrhage
    - Acute hemorrhage may be echogenic on ultrasound
    - Makes tear less readily visible on ultrasound
  - May occur at insertion (avulsive-type), at tendon surface, or within tendon substance (intrasubstance)
  - Look for associated secondary signs of tear
    - Flattening or indentation of tendon surface
    - Loss of continuity of tendon fibrillar pattern
    - Widening of gap on dynamic movement
    - ± compression of hematoma in gap on dynamic scanning
  - Chronic tears may also be filled with echogenic fat, particularly in Achilles tendon
  - Partial thickness tear
    - Focal discontinuity of tendon not involving all tendon fibers
    - Lack of complete tendon retraction
    - Occurs with moderate to severe tendinosis
    - ± dystrophic calcification
    - ± bursitis
    - ± reactive bony changes
  - Full thickness tear
    - Collapsed synovial sheath may be mistaken for attenuated tendon, particularly in smaller tendons (e.g., finger flexors and biceps tendon)
  - Peritendinitis
    - Edema and hyperemia of peritendinous tissues
- **Avulsion Injury of Tendon**
  - Commonly at extensor digitorum of fingers, Achilles tendon, tibialis posterior tendon
  - Ossified fragment can be seen at distal end of tendon mimicking ossification within tendon
  - Look for loss of normal fibrillation distal to ossified fragment
- **Accessory Ossicle**
  - Most common accessory ossicles within tendon are accessory navicular bone (within posterior tibialis tendon) and os peroneum (within peroneus longus)
  - May be confused with dystrophic ossification
    - Accessory ossicle has smooth convex superficial border, while dystrophic ossification is more irregular
  - Fractures or displacement of os peroneum can be clue to peroneus longus tendon tear
- **Suture Material Within Tendon**
  - Often nonabsorbable and thus may be visible many years after tendon repair
    - Easily recognized as tubular echogenic material within tendon substance
- **Foreign Body Within Tendon**
  - Ultrasound is excellent at detecting foreign bodies
  - Foreign body echogenicity depends on the composition (e.g., wood, glass, metal) and shape
    - Most foreign bodies are hyperreflective with posterior acoustic shadowing or reverberation artifact
  - If ultrasound is negative in suspicious acute clinical setting, repeat ultrasound 1 week later as hypoechoic inflammatory response or granulation tissue may make foreign body more conspicuous

Calcific Tendinitis



Longitudinal ultrasound shows a large area of calcific tendinitis ➔ just proximal to the insertional area of the supraspinatus tendon ➔.

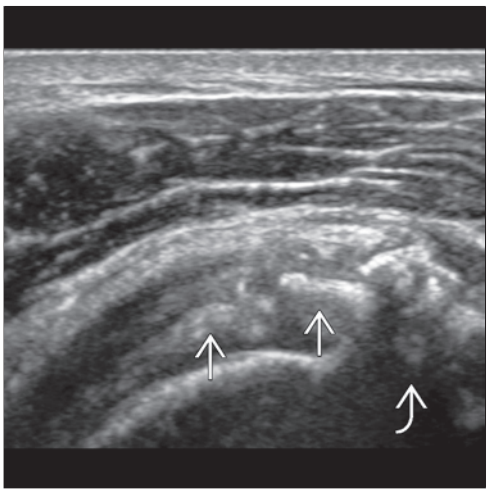
Calcific Tendinitis



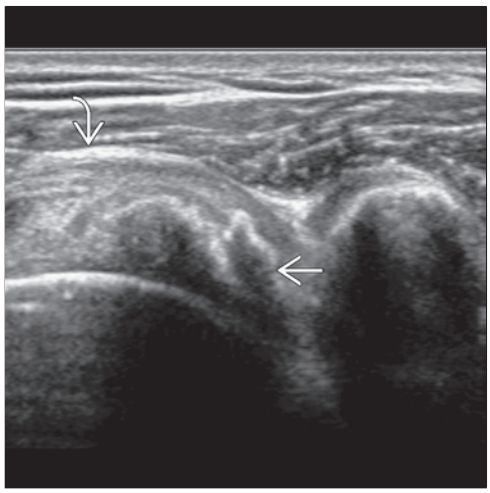
Transverse ultrasound shows a smaller focus of calcification ➔ within the supraspinatus tendon ➔ close to the insertional area, compatible with calcific tendinitis. The humerus ➔ is normal.

TENDON HYPERECHOGENICITY

Calcific Tendinitis

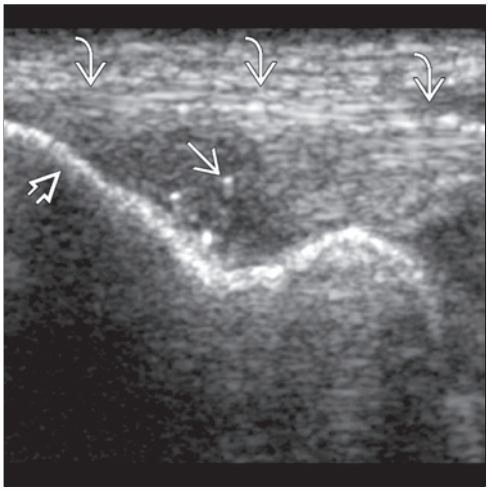


Calcific Tendinitis

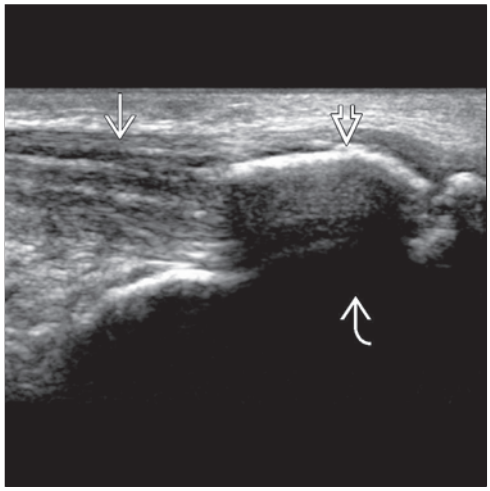


(Left) *Longitudinal ultrasound shows severe nonconfluent calcific tendinitis within the supraspinatus tendon obscuring the insertional area. **(Right)** Longitudinal ultrasound shows an area of calcific tendinitis within the supraspinatus tendon. Moderate supraspinatus tendinosis is present. Tendinosis is a frequent, but not invariable, accompaniment of calcific tendinitis.*

Calcification Within Tendinosis

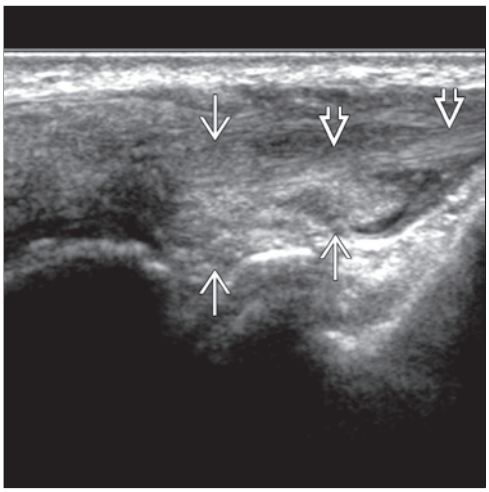


Calcification Within Tendinosis

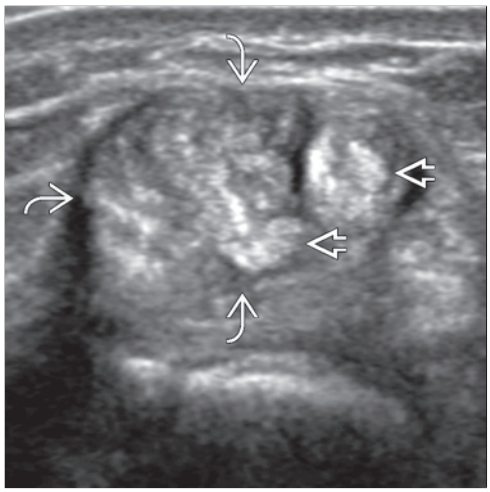


(Left) *Longitudinal ultrasound shows a focal area of hypoechoic tendinosis, associated with early calcification with "comet tail" artifacts at the common extensor tendon origin at the lateral humeral condyle. **(Right)** Longitudinal ultrasound shows a large area of calcification or ossification within the Achilles tendon obscuring the tendon insertion area on the calcaneum.*

Gout



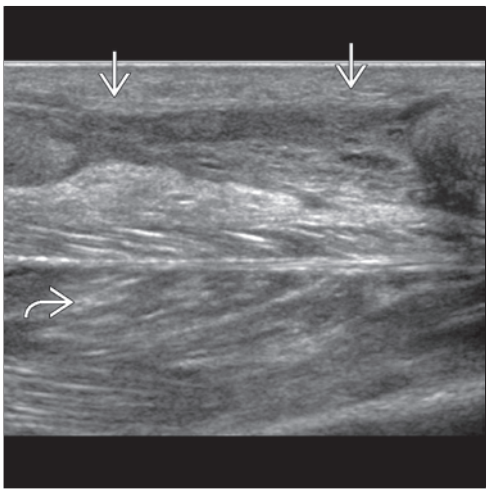
Gout



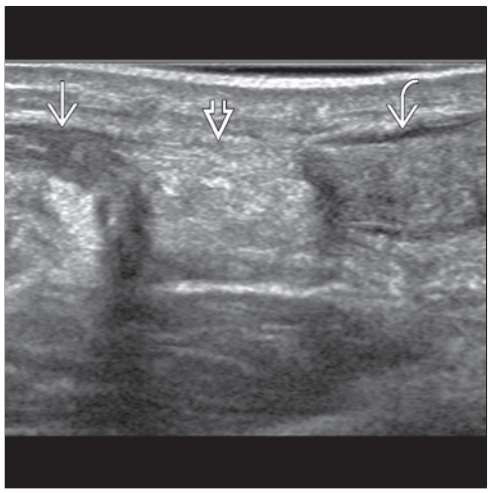
(Left) *Longitudinal ultrasound shows echogenic material encasing the extensor carpi ulnaris tendon distally, compatible with peritendinous crystal deposition. **(Right)** Transverse ultrasound of the same tendon shows the gouty echogenic material distending the extensor carpi ulnaris tendon sheath. Crystals are also deposited within the tendon leading to tendon hyperechogenicity though no acoustic shadow is present.*

TENDON HYPERECHOGENICITY

Tendon Tear

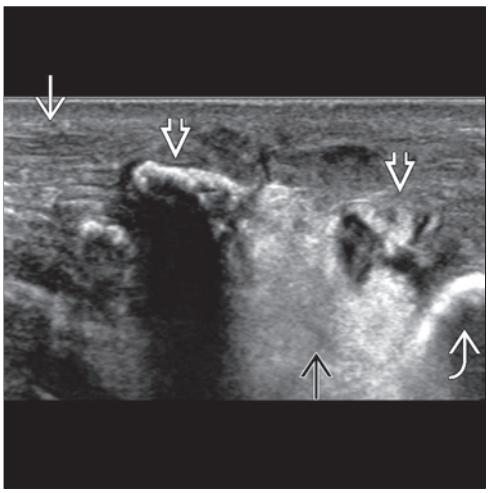


Tendon Tear

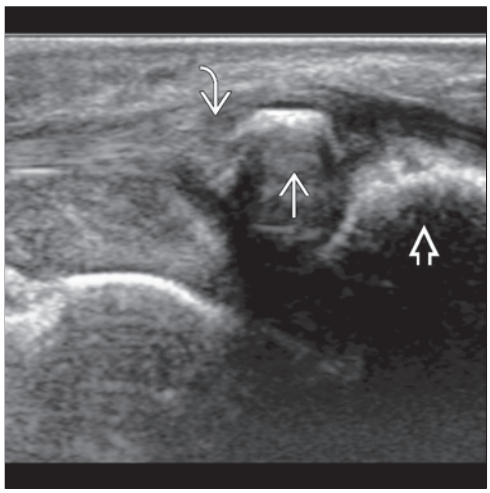


(Left) *Longitudinal ultrasound shows a complete chronic rupture of the Achilles tendon. There is a large retraction gap. The chronic tear is filled with slightly echogenic fibrous tissue. The soleus muscle is mildly atrophic. **(Right)** Longitudinal ultrasound of an acute full thickness Achilles tendon tear shows a gap filled with echogenic edematous fat. The swollen proximal and distal ends of the tendon are shown.*

Avulsion Injury of Tendon

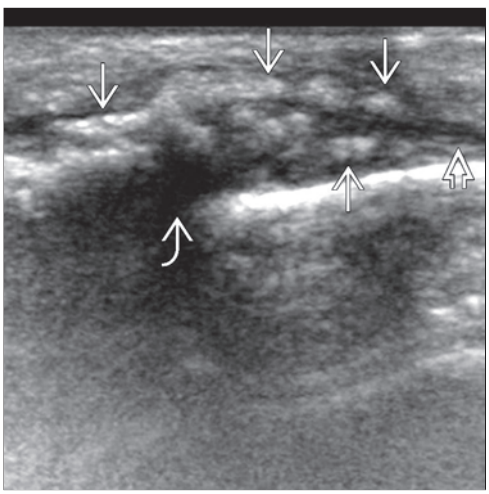


Accessory Ossicle

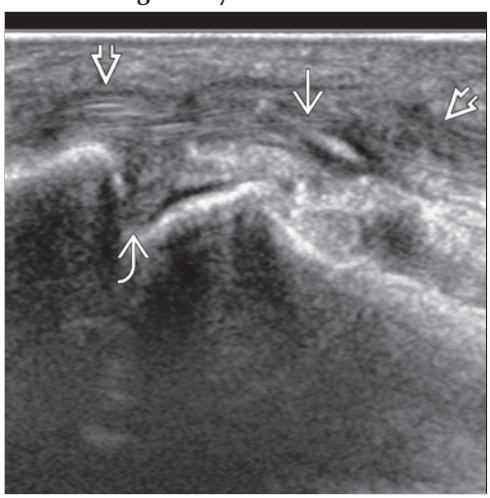


(Left) *Longitudinal ultrasound of the Achilles tendon shows a fragmented avulsion fracture from the posterior calcaneal tuberosity insertion with proximal retraction. The gap is filling up with echogenic hematoma. **(Right)** Longitudinal ultrasound shows a normal accessory bone near the insertion of the posterior tibialis tendon into the navicular bone. The distal end of the posterior tibialis tendon normally expands near to the bony insertion.*

Suture Material Within Tendon



Foreign Body Within Tendon



(Left) *Longitudinal ultrasound of the proximal interphalangeal joint of the ring finger shows several small hyperechoic foci within and around the extensor digitorum tendon due to surgical suture without significant posterior acoustic shadowing. **(Right)** Longitudinal ultrasound of the middle finger shows an echogenic foreign body lying obliquely within the flexor digitorum tendon just proximal to the metacarpophalangeal joint.*

TENDON SWELLING

DIFFERENTIAL DIAGNOSIS

Common
- Tendinosis

Less Common
- Acute Proliferative Tenosynovitis
- Acute Exudative Tenosynovitis
- Chronic Tenosynovitis (Active)
- Chronic Tenosynovitis (Inactive)
- Gout
- Xanthomatosis
- Amyloidosis

ESSENTIAL INFORMATION

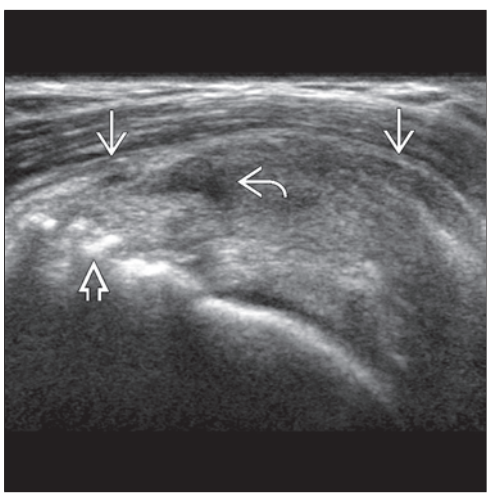
Key Differential Diagnosis Issues
- Need to determine whether primary pathology affects tendon or tendon sheath
- Distinction between tendinosis & tenosynovitis has important therapeutic & prognostic implications
  - Tendinosis: Tendon disease with secondary involvement of peritendinous structures
    - Tenosynovitis: Disease of tendon sheath with secondary involvement of tendon
  - Tendinosis results from microtears, proteoglycan deposition, & collagen disorganization
    - Tenosynovitis results from tendon sheath inflammation due to inflammatory mediators, repetitive microtrauma, crystals, or bacteria
  - Tendinosis is not primary inflammatory disease
    - Tenosynovitis is primary inflammatory disease
  - Tendinosis effects any tendon
    - Tenosynovitis only affects tendons with tendon sheath
  - Tendinosis often affects only segment of tendon
    - Tenosynovitis usually affects all of tendon contained by tendon sheath
  - Tendinosis is often subclinical
    - Tenosynovitis is rarely subclinical
  - Tendinosis frequently predisposes to tendon tear or rupture
    - Tenosynovitis infrequently predisposes to tendon tear or rupture
  - Tendinosis treated primarily by rest and is likely to recur
    - Tenosynovitis treated primarily by anti-inflammatory agents and less likely to recur
- Note that mild tendon & tendon sheath swelling occurs in presence of cellulitis or edema as a feature of generalized soft tissue swelling
  - Do not misdiagnose as tenosynovitis

Helpful Clues for Common Diagnoses
- **Tendinosis**
  - Focal, nodular, or diffuse tendon enlargement with loss of normal fibrillar echotexture
  - Very common, especially in rotator cuff tendons and long head of biceps tendon
    - Supraspinatus > infraspinatus > subscapularis > teres minor
    - Long head of biceps near top of bicipital groove
  - Also common in non-rotator cuff tendons
    - Lower limbs: Achilles tendon, patellar tendon, posterior tibialis tendon
    - Upper limbs: Common extensor tendons of elbow
  - Progressive tendon thickening from mild to severe
  - Progressive loss of normal fibrillar pattern
  - Increasing tendon hypoechogenicity
  - Tendon hyperemia
    - More common in some tendons than others
    - Uncommon around shoulder, hip, & posterior aspect of knee
    - Common around elbow, wrist, anterior aspect of knee, & ankle/foot
  - ± partial tear
    - Intrasubstance, avulsive-type, or full thickness tears
    - Occur with moderate to severe tendinosis
    - Should not be confused with dilated vascular channels within hyperemic tendon
  - ± tendon sheath effusion
  - ± peritendinitis with inflammation of soft tissues around tendon or paratenon
    - Important to note as it will respond to anti-inflammatory treatment
  - ± reactive changes at bony insertional area
    - Hyperostotic or resorptive changes
    - Marrow changes not seen on ultrasound
  - ± dystrophic calcification within tendon
  - ± bursitis (Achilles, common extensor)

Helpful Clues for Less Common Diagnoses
- **Acute Proliferative Tenosynovitis**
  - Due to inflammation or infection
  - Synovial proliferation within tendon sheath > tendon sheath fluid
  - Hyperemia predominates around, rather than within, tendon sheath
  - Commonly affects common flexor tendon sheath (ulnar bursa) of hand
    - Ulnar bursa extends from just proximal to just distal to carpal tunnel
    - Communicates with flexor digitorum tendon sheath in ~ 10% normal subjects and radial bursa in ~ 5% of normal subjects
    - Ulnar bursal infection may also spread to space of Parona
    - Space of Parona: Potential space superficial to pronator quadratus muscle, which extends to midforearm
- **Acute Exudative Tenosynovitis**
  - Due to acute infection
  - Fluid accumulation within sheath with little or no synovial proliferation
  - Speckled echogenic fluid
    - Speckles due to aggregates of purulent material
  - Mild to moderate tendon swelling
    - ± indistinct tendon margins if infection established & severe
  - Hyperemia around, rather than within, tendon sheath
  - Infection may spread to surrounding tissues
  - May result from foreign body following penetrating trauma
  - Ultrasound-guided aspiration helpful to identify infective organism
- **Chronic Tenosynovitis (Active)**
  - Due to inflammation or infection (TB or non-TB)
  - Markedly thickened tendon sheath in TB
  - Hyperemia is predominantly within tendon sheath
  - Synovium is visibly hypervascular on color Doppler imaging; in acute tenosynovitis, synovium is not visibly hypervascular

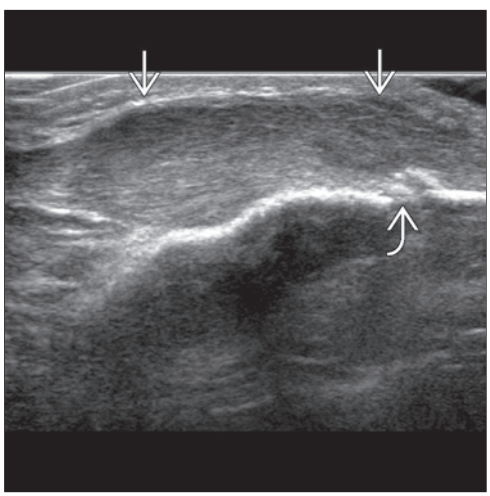
- **Chronic Tenosynovitis (Inactive)**
  - Tendon sheath distension with fluid or synovial proliferation, though little or no hypervascularity
    - If adhesions present, tendon sheath may be markedly distended focally & noncompressible
  - Overlap exists among various subtypes of tenosynovitis
- **Gout**
  - Tophi within tendons are seen commonly in chronic crystal deposition disease
  - Located around joints, ligaments, & fascial insertions
  - Tophi are more common with gout
  - Pseudogout: Calcium pyrophosphate dihydrate crystal deposition
  - Tophi range from soft tophi to hard tophi
    - Soft tophi: Little mineralized component with scattered crystal aggregates & "comet tail" artifacts
    - Hard tophi: Heavily mineralized component such that only superficial margin is seen due to dense posterior acoustic shadowing
  - Other typical features
    - Adjacent to bursa/tendon
    - Calcified irregular hypervascular mass
- **Xanthomatosis**
  - Feature of familial hyperlipidemia
  - Accumulation of foamy histiocytes, cholesterol ester, & giant cells within tendons
    - Achilles tendon > patellar tendon > extensor tendons of hands & feet
  - Focal or more generalized tendon swelling, increased tendon hypoechogenicity, & mild hypervascularity
  - Difficult to distinguish from tendinosis though some ultrasound signs are helpful
  - Patients with tendon swelling due to xanthomatosis tend to have
    - More nodular intratendinous hypoechoic areas (xanthomas) with less hyperemia
    - Symmetrical tendon swelling
    - Few or none of the secondary changes seen in tendinosis (insertional cortical irregularity, peritendinitis, tendon tears)
    - More puncture, more diffuse, & smaller areas of intratendinous dystrophic calcification
    - Known familial hyperlipidemia
    - Features of atherosclerosis (increased intima-media thickness)
    - Nonpainful tendon swelling
  - Xanthomatosis may regress with lipid-lowering treatment
- **Amyloidosis**
  - Accumulation of protein fibrils which become insoluble and are deposited either in specific tissues (localized amyloidosis) or throughout body (generalized amyloidosis)
  - Extracellular deposition of protein fibrils (amyloid) in body tissues
    - Over 20 different protein fibrils may produce amyloidosis
    - Diagnosis dependent on histology of biopsy specimen (Congo red staining & apple-green birefringence under polarized light)
  - May be primary or secondary
  - **Primary amyloidosis**
    - Genetically inherited disorder of protein metabolism
  - **Secondary amyloidosis**
  - Usually seen in patients with long-term hemodialysis
    - Cannot filter β2-microglobulin that accumulates in body
  - Also associated with myeloma & chronic inflammatory states
    - Increased production of protein fibrils
  - Amyloid deposited in synovium, joint capsule, tendons (supraspinatus, biceps, flexor digitorum tendons), ligaments, nerves, & intervertebral disc
    - Hypoechoic tendon thickening
    - ± tendon sheath or bursal effusion & hypervascularity with hypoechoic, inhomogeneous nodular thickening around tendons
  - Associated with spondyloarthropathy & lytic paraarticular bone lesions

Tendinosis



Longitudinal ultrasound shows a markedly thickened and diffusely hypoechoic supraspinatus tendon ➔ compatible with severe tendinosis. There is insertional cortical irregularity ➔ and small tendon tears ➔.

Tendinosis

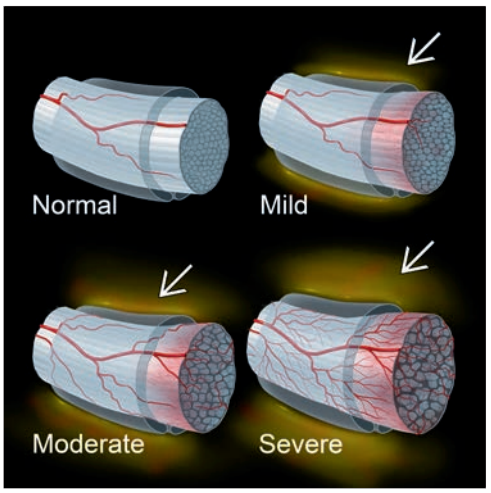


Longitudinal ultrasound of distal patellar tendon shows severe focal thickening with hypoechogenicity and loss of normal fibrillar pattern ➔ due to severe tendinosis. Mild tibial tuberosity cortical irregularity is present ➔.

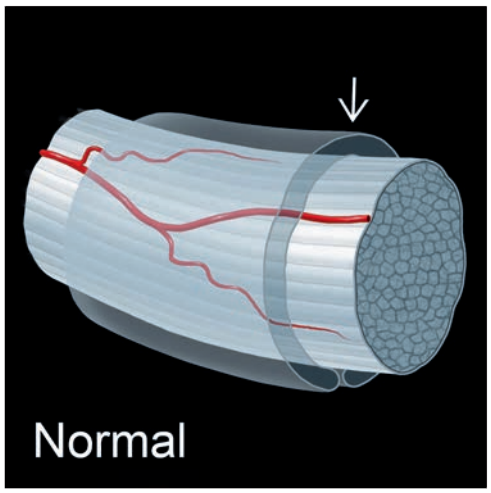
TENDON SWELLING

(Left) *Graphic shows grades of tendinosis. The severity of tendinosis and the degree of surrounding peritendinitis ➔ should be independently graded. The likelihood of tendon tear is greater the more severe the tendinosis. The likelihood of clinical response to antiinflammatory medication is greater the more severe the peritendinitis.* ***(Right)*** *Graphic shows normal tendon structure with tendon sheath ➔ shown for illustrative purposes. Most tendons do not have a tendon sheath.*

Tendinosis

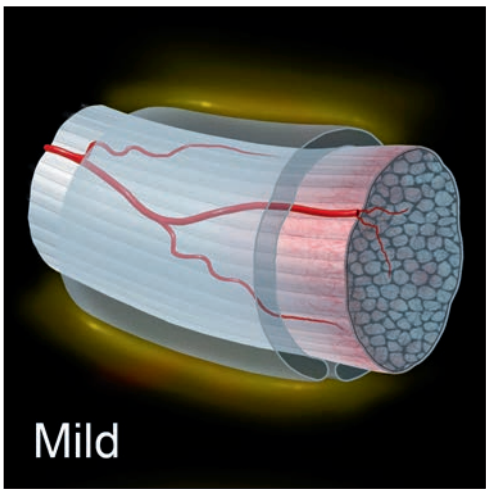


Normal Tendon

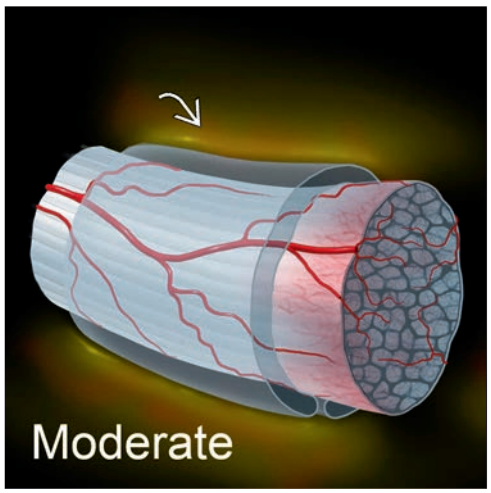


(Left) *Mild tendinosis with mild tendon swelling (due to proteoglycan accumulation) and mild intratendinosis hyperemia is shown. Intrinsic vascularity is not a feature of normal tendons.* ***(Right)*** *Moderate tendinosis with more severe tendon swelling, proteoglycan deposition, and intratendinosis hyperemia is shown. Although tendinosis and peritendinitis (seen as peritendinous edema and hyperemia) ➔ severity are broadly interrelated, both features should be independently graded as mild, moderate, or severe.*

Tendinosis

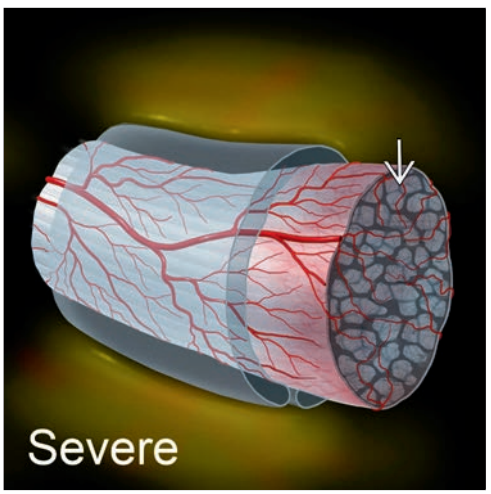


Tendinosis

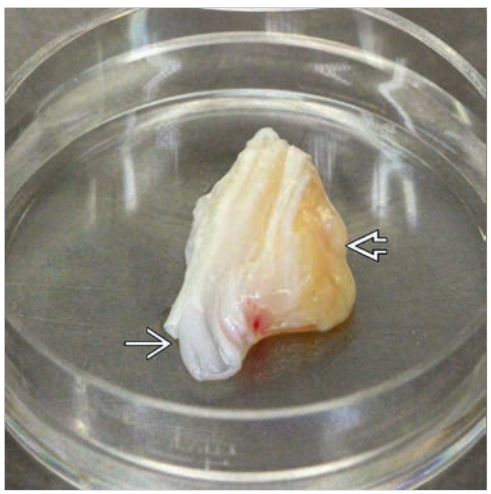


(Left) *Severe tendinosis with more severe tendon swelling and intratendinosis hyperemia ➔ (manifest on US as tendon swelling, tendon hypoechogenicity, loss of fibrillar echopattern, and ↑ tendon hyperemia) is shown. Mild tendon sheath swelling is usually seen, though this is a manifestation of peritendinitis rather than primary tendon sheath inflammation.* ***(Right)*** *Photograph shows patellar tendinosis. The normal tendon is glistening white ➔, and the area with severe tendinosis is yellow ➔. (Courtesy of C. K. Ming, MD.)*

Tendinosis

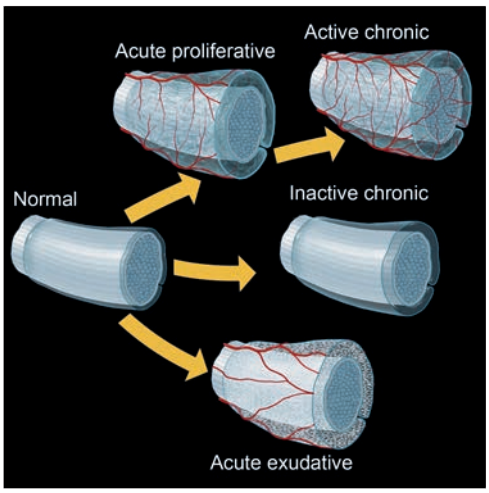


Tendinosis

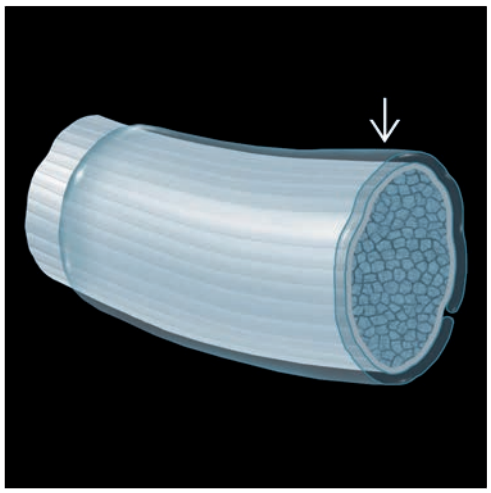


TENDON SWELLING

Tenosynovitis

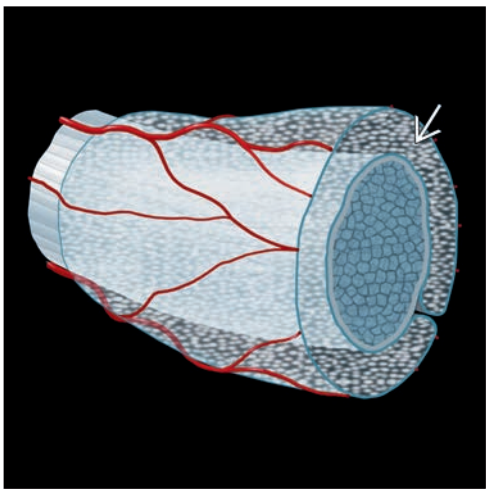


Normal Tendon

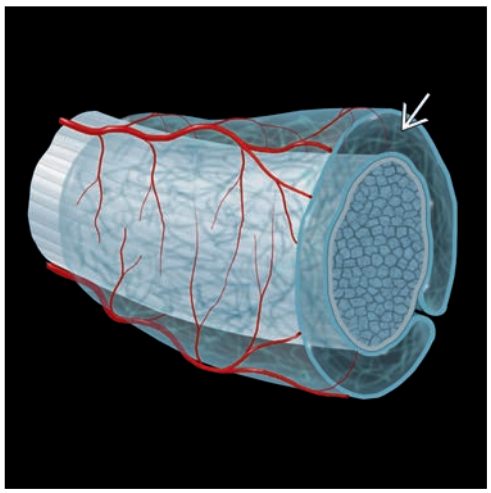


(Left) *Graphic shows different types of tenosynovitis. Tenosynovitis is a disease of the tendon sheath. Unlike tendinosis, which can affect any tendon, tenosynovitis can only affect those tendons with a tendon sheath.* ***(Right)*** *Graphic shows normal tendon and tendon sheath ➔ for comparative purposes. Most, but not all the tendons, of the wrist/hand and the ankle/foot have a tendon sheath. The long head of biceps has a tendon sheath. The patellar and Achilles tendons have a paratenon. All other tendons without a tendon sheath cannot be affected by tenosynovitis.*

Acute Exudative Tenosynovitis

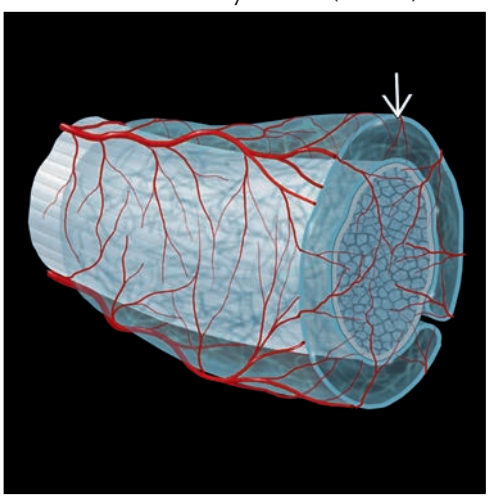


Acute Proliferative Tenosynovitis

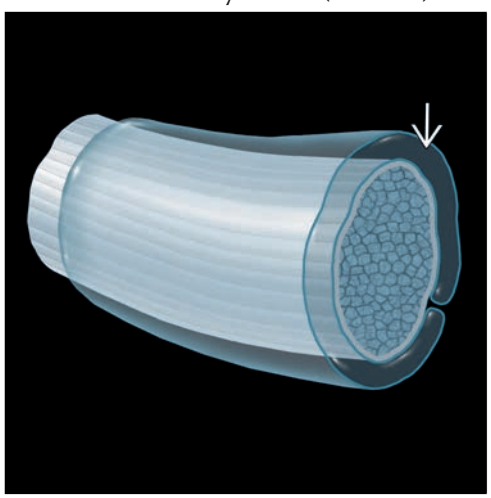


(Left) *Graphic shows acute exudative tenosynovitis, usually secondary to bacterial infection/ penetrating trauma and is rapidly progressive. Purulent exudate ➔ can be aspirated. Hyperemia occurs around rather than within the tendon sheath.* ***(Right)*** *Graphic shows acute proliferative tenosynovitis. This is a proliferative rather than an exudative tenosynovitis usually due to repetitive trauma or a systemic inflammatory disorder. Tendon swelling occurs due to synovial proliferation ➔ with a mild serous exudate. Hyperemia is limited to the tendon sheath surface.*

Chronic Tenosynovitis (Active)



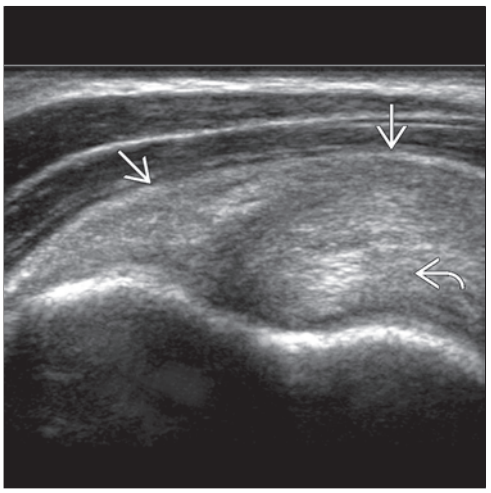
Chronic Tenosynovitis (Inactive)



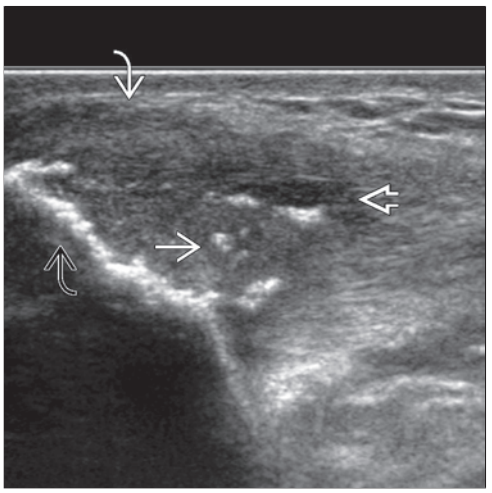
(Left) *Graphic shows chronic proliferative tenosynovitis. Mature hyperemic synovial proliferation ➔ fills the distended tendon sheath. Hyperemia may extend into tendon. Tendon will have normal echogenicity and be only slightly enlarged due to edema (as opposed to more severe tendon swelling and hypoechogenicity with tendinosis).* ***(Right)*** *Graphic shows chronic inactive tenosynovitis. The tendon sheath is distended with serous fluid ➔. This distension may sometimes be severe and localized due to tendon sheath adhesions. Little or no hyperemia is present.*

TENDON SWELLING

Tendinosis

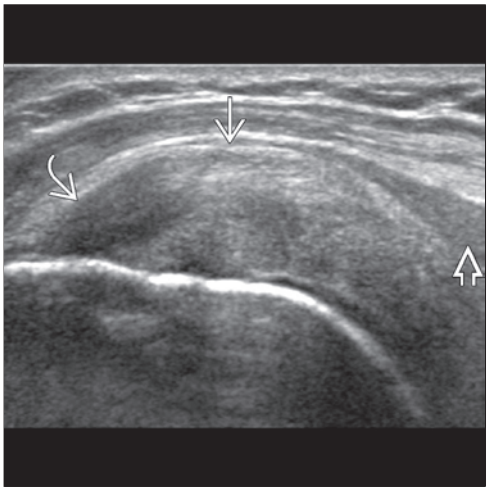


Tendinosis

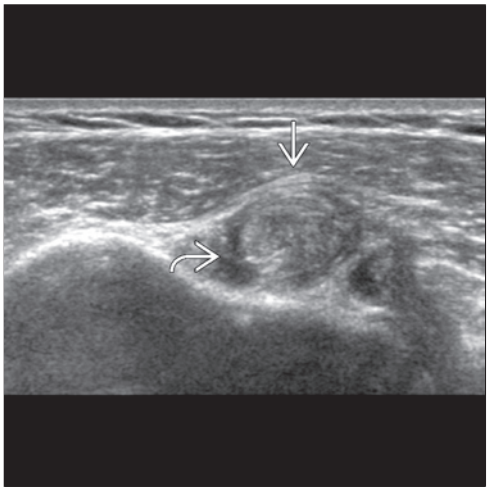


(Left) *Longitudinal ultrasound shows a diffusely thickened and hypoechoic supraspinatus tendon indicative of severe tendinosis. Some preservation of the fibrillary pattern is present.* ***(Right)*** *Longitudinal ultrasound of the elbow shows a severely thickened common flexor tendon origin with tendon hypoechogenicity, small foci of dystrophic calcification, a small intrasubstance tear, and moderate insertional cortical irregularity, all due to tendinosis.*

Tendinosis

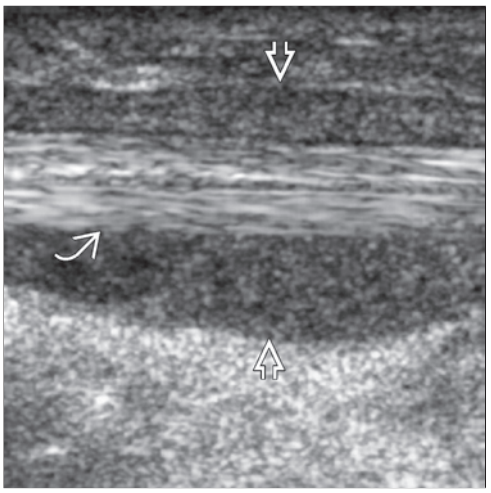


Tendinosis

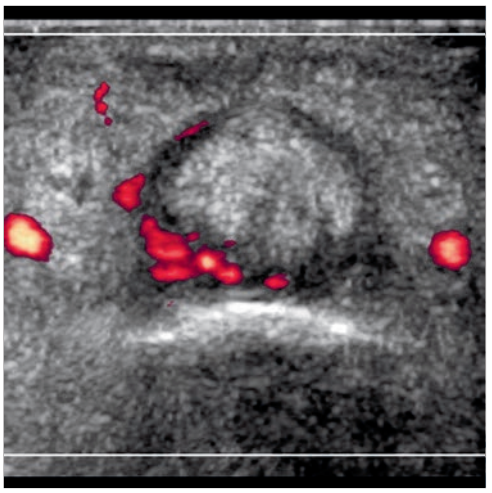


(Left) *Longitudinal ultrasound shows moderate-severity supraspinatus tendinosis. Note the hypoechoic anisotropic effect. There is distension of the subacromial-subdeltoid bursa with echogenic fluid, due to proteinaceous fluid content.* ***(Right)*** *Transverse ultrasound shows severe biceps tendinosis. The tendon is rounded and heterogeneous with an irregular peripheral contour. There is minimal surrounding synovial proliferation.*

Acute Exudative Tenosynovitis

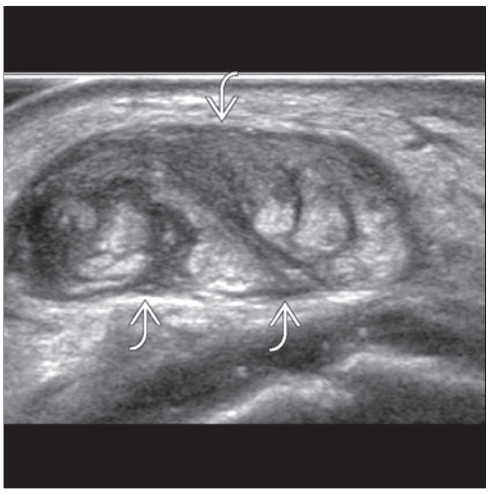


Acute Proliferative Tenosynovitis

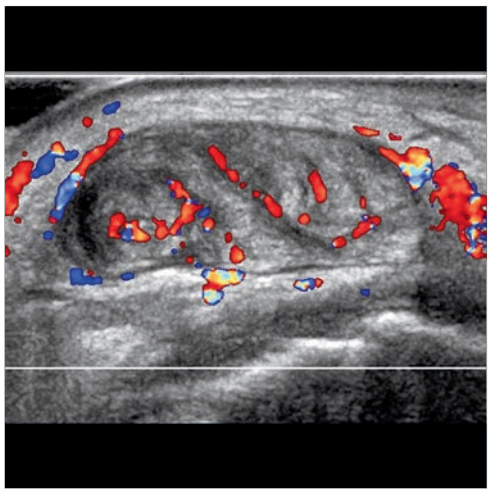


(Left) *Longitudinal ultrasound shows acute exudative tenosynovitis of the middle finger with distension of the flexor digitorum tendon sheath by fluid containing small echogenic aggregates. The flexor tendons are slightly swollen. Purulent fluid was aspirated which grew Staphylococcus aureus.* ***(Right)*** *Transverse color Doppler ultrasound of flexor digitorum of middle finger shows moderate tenosynovial hyperemia due to synovial proliferation and compatible with acute proliferative tenosynovitis.*

Chronic Tenosynovitis (Active)

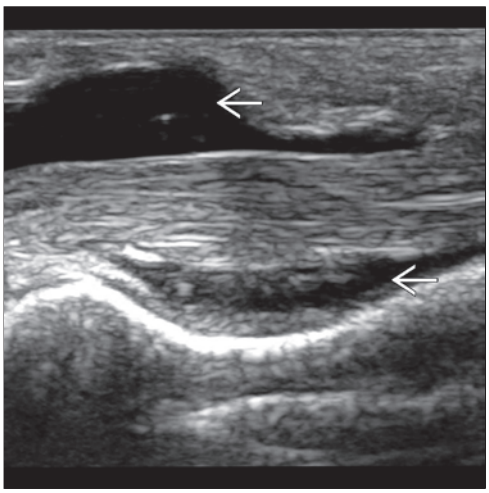


Chronic Tenosynovitis (Active)



(Left) *Transverse ultrasound of the extensor digitorum communis in a patient with progressive wrist swelling for 3 months shows severe synovial thickening surrounding the mildly swollen tendons, suggestive of chronic tenosynovitis.* ***(Right)*** *Transverse color Doppler ultrasound of the same patient shows severe peritendinous hyperemia indicative of active chronic tenosynovitis.*

Chronic Tenosynovitis (Inactive)

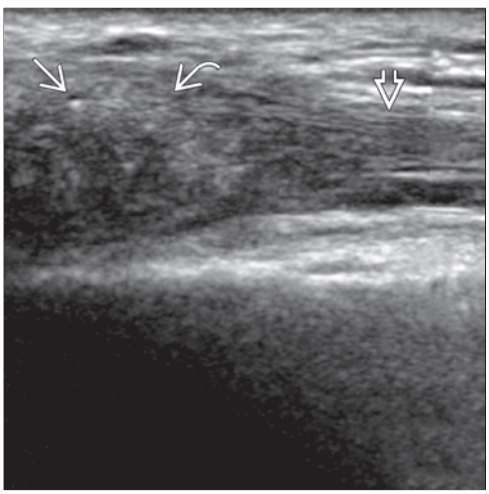


Gout

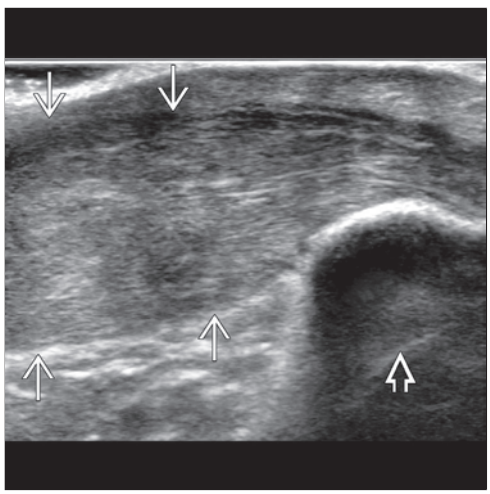


(Left) *Longitudinal ultrasound of the ring finger shows a moderate amount of largely anechoic fluid present within the flexor digitorum tendon sheath. Ultrasound-guided aspiration yielded gelatinous material consistent with inactive chronic tenosynovitis.* ***(Right)*** *Longitudinal ultrasound of the wrist in a patient with known gout shows marked distension of common extensor tendon sheath with small and large crystal aggregates ("snowstorm" appearance) due to a gouty tenosynovitis.*

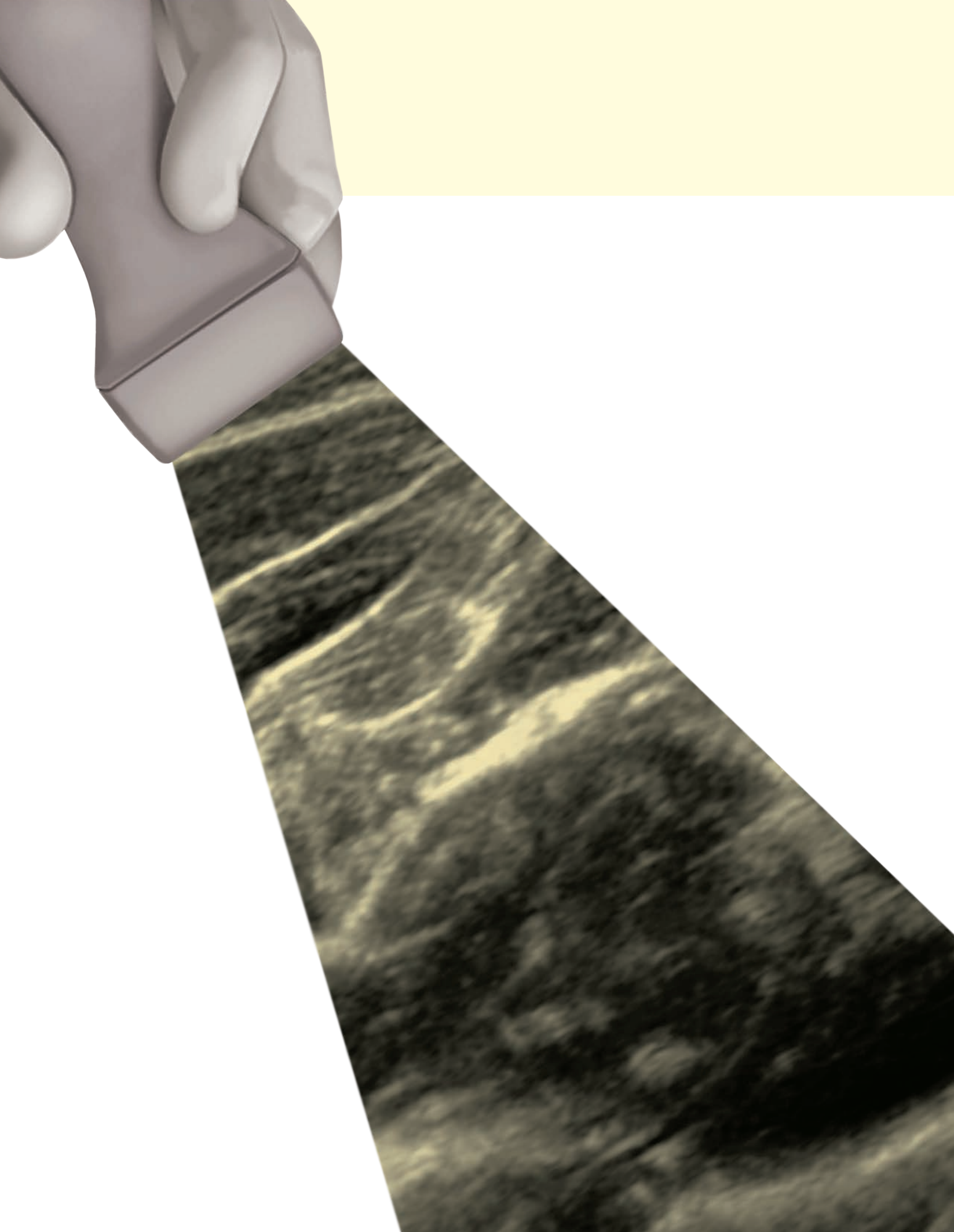
Gout



Xanthomatosis



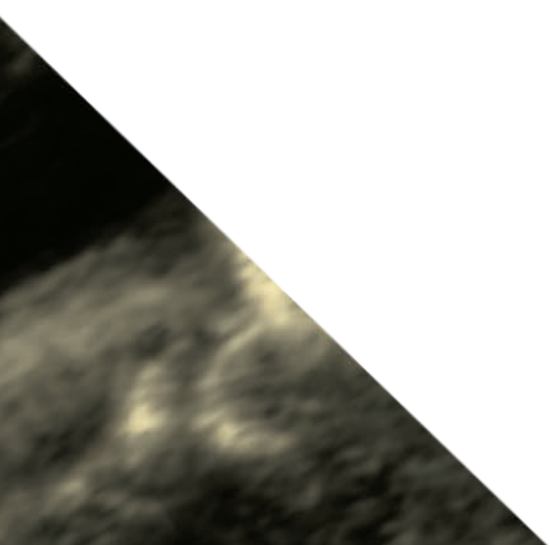
(Left) *Longitudinal ultrasound of the distal forearm shows a soft gouty tophus containing a few small echogenic foci with "comet tail" artifacts within the flexor digitorum profundus tendon.* ***(Right)*** *Longitudinal ultrasound of the Achilles tendon in a patient with familial hypercholesterolemia shows diffuse tendon swelling close to the calcaneal insertion due to deposition of cholesterol-rich lipid within the tendon.*



SECTION 3

Nerve, Fascia, and Bone

Swollen Nerve **III**-3-2
Fascial Lesion **III**-3-8
Bone Surface Lesion **III**-3-14



SWOLLEN NERVE

DIFFERENTIAL DIAGNOSIS

Common
- Nerve Compression
- Nerve Sheath Tumor

Less Common
- Nerve Injury
- Perineural Fibrosis
- Intraneural Lipoma
- Fibrolipomatous Hamartoma
- Intraneural Ganglion
- Metastases
- Acromegaly
- Charcot-Marie-Tooth Disease
- Leprosy

ESSENTIAL INFORMATION

Key Differential Diagnosis Issues
- Familiarity with appearances & course of main peripheral nerves is essential to identifying nerve disorders
- Nerves show honeycomb-like pattern on transverse imaging
  - Roundish, hypoechoic fascicles within hyperechoic background of epineurium
  - Best to identify nerve at specific location, then follow it distally or proximally in transverse plane
  - Longitudinal plane useful when assessing for nerve trauma & tumors
- When assessing nerve compression, important to measure cross-sectional area (CSA) of nerve at specific locations
  - Continuous boundary-tracing of nerve provides more correct area measurement than best-fitting ellipse method
  - Contralateral side is unreliable internal reference, as contralateral, subclinical, compressive neuropathy is common
- When assessing noncompressive nerve disorder, comparison with asymptomatic contralateral side is very helpful

Helpful Clues for Common Diagnoses
- **Nerve Compression**
  - Most commonly occurs within fibroosseous tunnels
    - Less commonly within muscular or fascial tunnels
  - Fibroosseous tunnels in upper limb
    - Carpal tunnel for median nerve compression
    - Cubital & Guyon tunnels for ulnar nerve compression
  - Fibroosseous tunnels in lower limb
    - Fibular neck for common peroneal nerve compression
    - Tarsal tunnel for tibial nerve compression
    - Intermetatarsal spaces for interdigital nerve fibroma
  - Controversial compressive neuropathies (i.e., questionable whether such neuropathies actually exist)
    - Thoracic outlet syndrome
    - Radial tunnel syndrome
    - Ulnar nerve entrapment at arcade of Struthers
    - Piriformis syndrome
  - Swelling of nerve proximal to or at site of compression is overriding sign of nerve compression
    - No nerve swelling indicates no nerve compression
  - Carpal tunnel syndrome
    - Measure CSA of median nerve at 4 sites
    - Proximal border pronator quadratus, proximal to tunnel inlet, at tunnel inlet & at tunnel outlet
    - Maximum CSA ≥ 12 mm² at any site → diagnostic of carpal tunnel syndrome
    - Maximum CSA = 9-12 mm² → borderline
    - Maximum CSA ≤ 9 mm² → normal
    - Also diagnostic of carpal tunnel syndrome if median nerve CSA in or near carpal tunnel > 4 mm² median nerve CSA at proximal pronator quadratus level
  - Cubital tunnel syndrome
  - Swelling of ulnar nerve with ↑ CSA within cubital tunnel
  - CSA ulnar nerve within cubital tunnel
    - Normal: < x 1.5 ulnar nerve CSA at mid-arm
    - Diagnostic of cubital tunnel syndrome: > x 2.5 ulnar nerve CSA at midarm
- **Nerve Sheath Tumor**
  - Tumor of peripheral nerve
    - Schwannoma: Tumor of Schwann cells lining axons
    - Neurofibroma: Tumor of connective tissue between axons
  - Hypoechoic, fusiform-shaped tumor of nerve
  - Thickening of entering or exiting nerve
    - Tumors arising from small nerves may not have visible thickening of parent nerve
  - Anechoic areas
    - Due to myxoid or fluid accumulation
    - Some schwannomas may be predominantly anechoic & cyst-like (ancient schwannoma)
  - Posterior acoustic enhancement
  - Moderately hyperemic on Doppler
  - ± hyperechoic areas
    - Due to hemorrhage or calcification
  - Malignant peripheral nerve sheath tumor is more likely if
    - Patient has neurofibromatosis type 1
    - Tumor is large (> 5 cm), ill defined, heterogeneous, &/or rapidly growing
  - FDG PET has quite high (~ 80-90%) sensitivity & specificity for diagnosing malignant peripheral nerve sheath tumor associated with neurofibromatosis

Helpful Clues for Less Common Diagnoses
- **Nerve Injury**
  - Most nerve injuries are clinically obvious
    - Limited need for imaging, particularly in penetrating trauma
    - Imaging indicated in equivocal cases or chronic cases
  - Most peripheral nerves can be well visualized with ultrasound
  - Ultrasound of nerve injury is used to assess whether nerve is
    - Not torn (neurapraxia), nerve conduction block
    - Partially torn (axonotmesis)
    - Completely torn (neurotmesis)
  - Swollen nerve caused by
    - Reparative fibrosis at site of tear
    - Traumatic neuroma: Tangled proliferative mass of axons, Schwann cells, and fibrosis

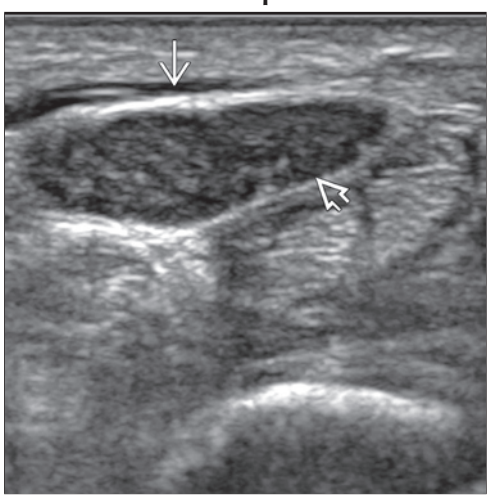
- **Perineural Fibrosis**
  - Common in brachial plexus following radiotherapy for carcinoma of breast or upper aerodigestive tract
  - Following injury to peripheral nerve or following excision of nerve sheath tumor
  - Localized nerve swelling with hyper- to hypoechoic fibrotic tissue surrounding & obscuring nerve outline
- **Intraneural Lipoma**
  - Arise from adipose tissue embedded in nerve
  - Most commonly of median or ulnar nerve
  - May cause compressive neuropathy
- **Fibrolipomatous Hamartoma**
  - Benign, fibrofatty malformation of peripheral nerve
  - Most cases present before 30 years of age
    - 1/3 associated with finger enlargement or macrodactyly (macrodystrophia lipomatosa)
  - Majority involve median nerve
    - Less frequently affects ulnar nerve, radial nerve, brachial plexus, or plantar nerves
  - Soft, slow-growing, fusiform swelling of nerve
    - ± increasing pain, tenderness, & diminished sensation
    - ± symptoms of compression neuropathy such as carpal tunnel syndrome
  - Markedly swollen nerve with coaxial cable like appearance
  - All neural elements are swollen to a comparable degree with thickened hypoechoic fascicles embedded in echogenic stroma background
- **Intraneural Ganglion**
  - May be extraneural or intraneural
  - Accumulation of myxoid fluid encased in fibrous capsule within nerve
    - Due to communication between joint & parent nerve along small articular branch
    - Synovial fluid tracts along small branch & accumulates in parent nerve
  - Hypoechoic mass within nerve, which can extend longitudinally along nerve
  - Can cause neural compression → pain, paresthesia, weakness & muscle atrophy
    - May be amenable to ultrasound-guided aspiration
- **Metastases**
  - Usually involve brachial plexus
    - Hypoechoic, irregular, hypervascular mass infiltrating brachial plexus
    - May need aspiration for cytology to differentiate from radiotherapy-induced perineural fibrosis
- **Acromegaly**
  - Peripheral nerves ~ 2x as large in acromegalic patients as normal subjects
  - Degree of nerve enlargement related to clinical control, duration, & insulin-like growth factor 1 level
- **Charcot-Marie-Tooth Disease**
  - Heterogeneous group of inherited peripheral nervous system disorders
    - Most common types are autosomal dominant types 1A, 2, & X-linked type
  - Onset usually before 30 years of age
    - Progressive peripheral weakness, ↓ tendon reflexes, peroneal muscle atrophy, pes cavus, & mild sensory loss
  - Ultrasound can show median nerve hypertrophy
    - Can allow differentiation of Charcot-Marie-Tooth type 1A from other types
    - Useful screening tool for next of kin who may need genetic assessment
- **Leprosy**
  - Chronic granulomatous disease due to *Mycobacterium leprae*
  - Affects peripheral nerves, upper respiratory tract mucosa, & skin
  - Wide spectrum of ultrasound abnormalities depending on disease duration, activity, ± compression
    - Early disease affects intradermal nerves → no visible ultrasound abnormality
    - Active disease → swelling of endoneural space, thickening of individual fascicles, & endoneural hyperemia
    - Longstanding inactive disease → nerves less swollen than in active disease with overall ↑ echogenicity & ↓ visibility of fascicles

Nerve Compression



Photograph of a patient with symptoms of carpal tunnel syndrome (CTS) shows visible volar wrist swelling due to severe median nerve compression proximal to carpal tunnel.

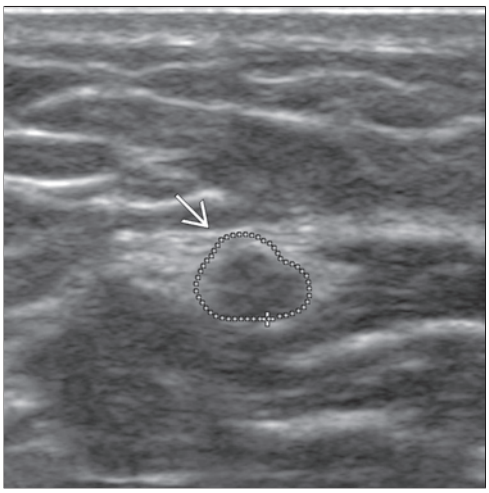
Nerve Compression



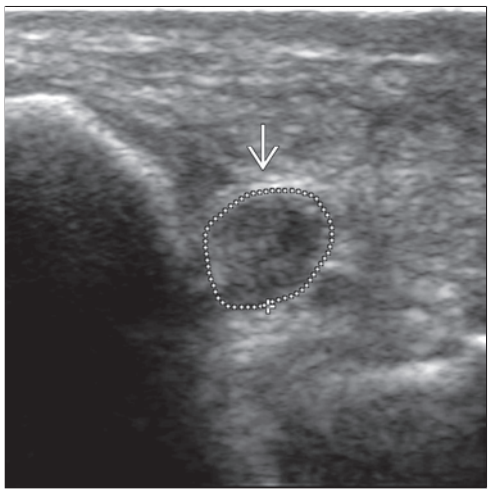
Transverse US of the same patient shows unusually severe (32 mm²) median nerve swelling deep to the flexor retinaculum at the tunnel inlet. In most CTS patients, the median nerve cross-sectional area is ~ 13-16 mm².

SWOLLEN NERVE

Nerve Compression

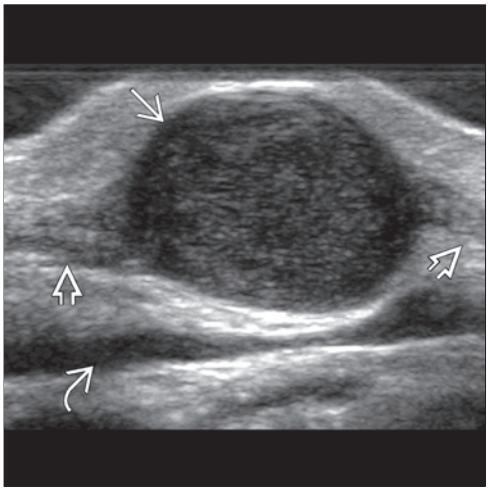


Nerve Compression

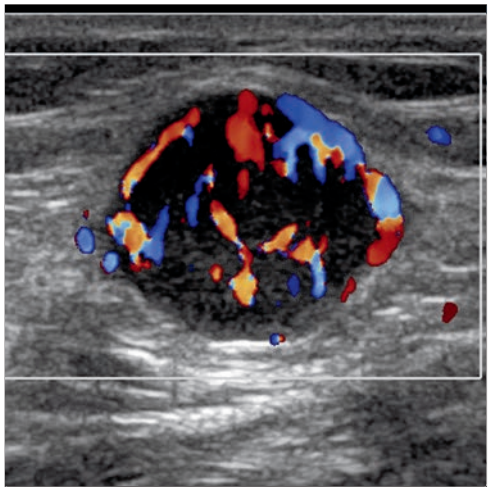


(Left) *Transverse ultrasound shows normal caliber (8 mm²) of ulnar nerve ➔ in the distal arm just proximal to the cubital tunnel in a patient with clinically suspected ulnar neuropathy.* ***(Right)*** *Transverse ultrasound in the same patient shows marked swelling (17 mm²) of the ulnar nerve ➔ within the cubital tunnel, indicative of cubital tunnel syndrome. One should also test for ulnar nerve subluxation by observing ulnar nerve movement in real time during passive elbow flexion.*

Nerve Sheath Tumor

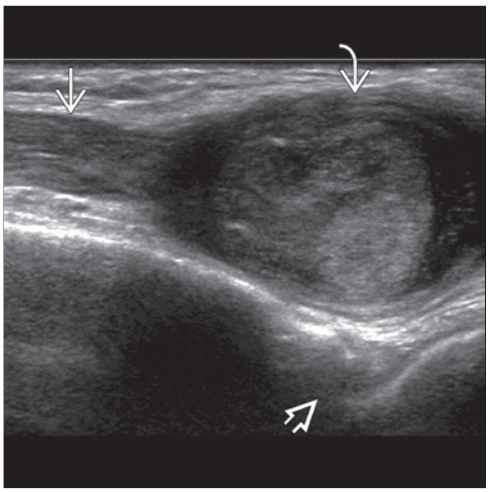


Nerve Sheath Tumor

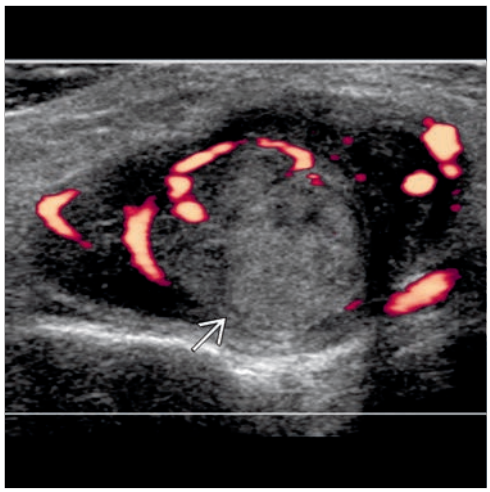


(Left) *Longitudinal ultrasound shows a medium-sized hypoechoic nerve sheath tumor ➔ of the medial sural cutaneous nerve ➔ between the medial and lateral heads of the gastrocnemius muscle (not shown). The thickened sural nerve alongside the tumor is visible. An underlying vein ➔ is moderately compressed.* ***(Right)*** *Longitudinal color Doppler ultrasound in the same patient shows characteristic hyperemia of the nerve sheath tumor.*

Nerve Sheath Tumor

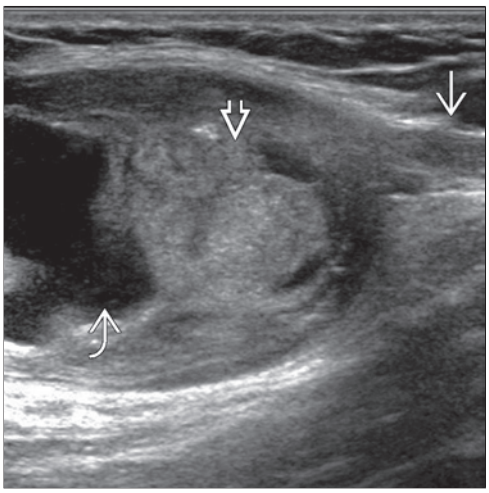


Nerve Sheath Tumor

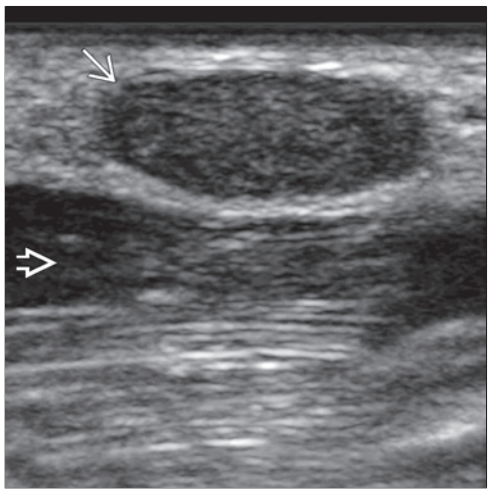


(Left) *Longitudinal ultrasound shows a nerve sheath tumor ➔ of the deep peroneal nerve ➔ anterior to the ankle joint ➔. The proximal part of the deep peroneal nerve is markedly thickened.* ***(Right)*** *Longitudinal power Doppler ultrasound of the same patient shows moderate marginal hyperemia. The central part of the tumor ➔ is relatively avascular and hyperechoic, most likely due to intratumoral hemorrhage.*

Nerve Sheath Tumor



Nerve Sheath Tumor

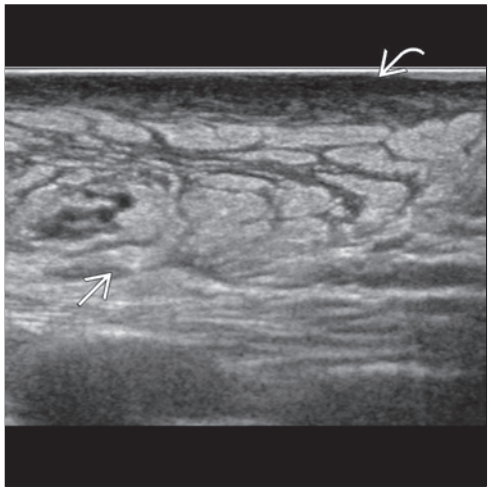


(Left) *Longitudinal ultrasound shows a tumor of the median nerve with solid and myxoid areas. The median nerve just distal to the tumor is slightly thickened.* ***(Right)*** *Longitudinal ultrasound shows a solid, oblong-shaped, hypoechoic mass ulnar to the hypothenar eminence near the base of the little finger. This was due to a nerve sheath tumor of a dorsal digital nerve. Most nerve sheath tumors arising from small nerves do not have a thickened neural tail.*

Nerve Sheath Tumor

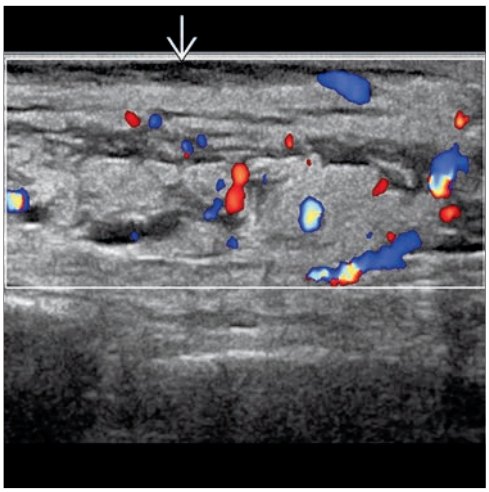


Nerve Sheath Tumor

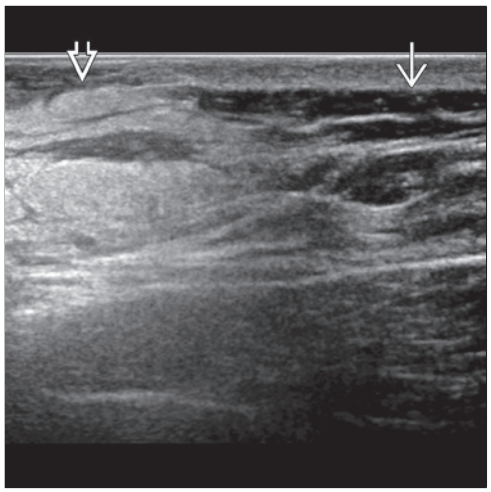


(Left) *Photograph of a patient with known neurofibromatosis shows a mass located deep to a large café au lait mark on the lower thoracic region posteriorly. This mass was enlarging clinically.* ***(Right)*** *Longitudinal ultrasound of the same patient shows thickened hyperechoic subcutaneous tissue and hypoechoic dermal and subdermal tissue. Biopsy revealed a myxoid spindle cell tumor consistent with a plexiform neurofibroma. There was no evidence of malignancy.*

Nerve Sheath Tumor



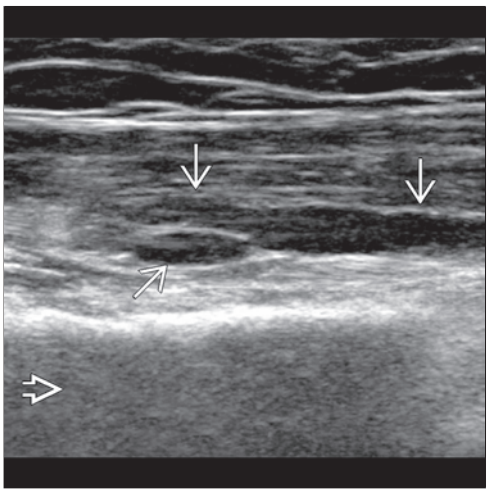
Nerve Sheath Tumor



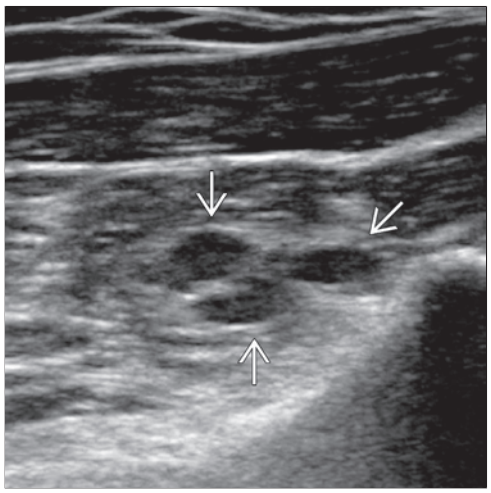
(Left) *Longitudinal color Doppler ultrasound of the same patient shows moderate hyperemia of the plexiform neurofibroma.* ***(Right)*** *Transverse ultrasound of the same patient shows normal hypoechoic subcutaneous fat at the end of the plexiform neurofibroma. The juxtaposition between normal hypoechoic subcutaneous fat and hyperechoic neurofibroma tissue can be readily appreciated.*

SWOLLEN NERVE

Nerve Sheath Tumor

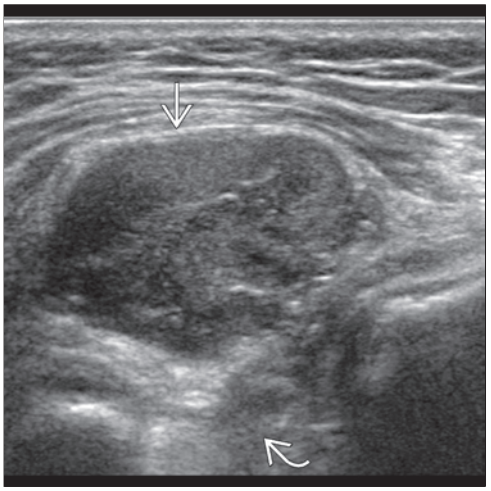


Nerve Sheath Tumor

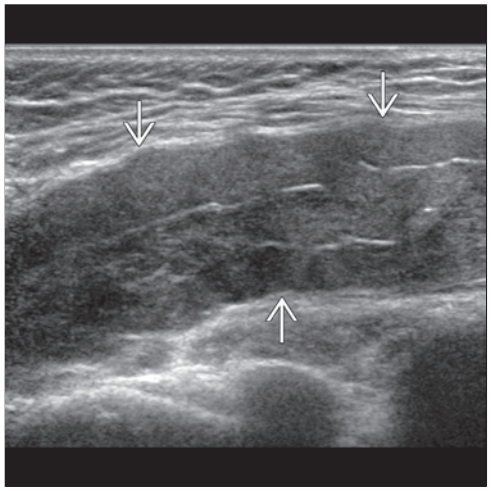


(Left) *Longitudinal ultrasound shows elongated plexiform nerve sheath tumor ➔ present in the proximal arm. The tumor was located between the brachialis and biceps muscles. The underlying humeral shaft ➔ is normal* ***(Right)*** *Transverse ultrasound of the same patient shows the tubular appearance ➔ of the plexiform neurofibroma. Plexiform neurofibromas occur almost invariably in patients with neurofibromatosis.*

Nerve Sheath Tumor

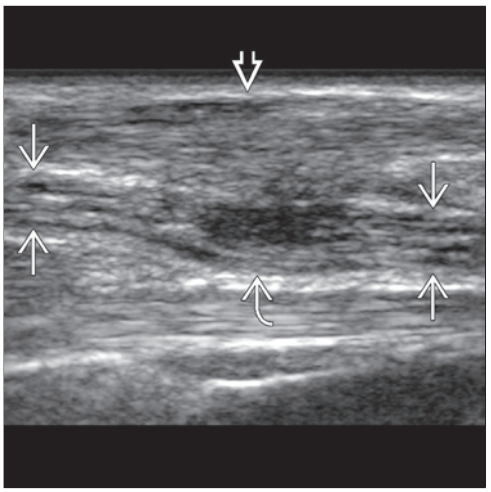


Nerve Sheath Tumor

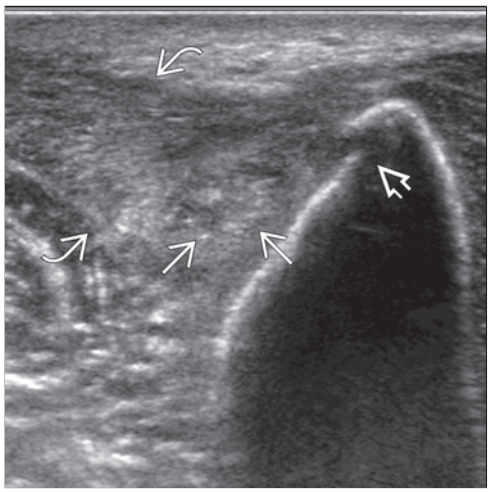


(Left) *Transverse ultrasound in a patient with 2-month history of lower limb pain and buttock swelling shows a large mass ➔ just external to the sciatic notch ➔.* ***(Right)*** *Longitudinal ultrasound in the same patient shows severe swelling of the sciatic nerve ➔ continuous with the more proximally located mass. Ultrasound-guided biopsy of the mass revealed malignant peripheral nerve sheath tumor. This patient did not have neurofibromatosis.*

Nerve Injury

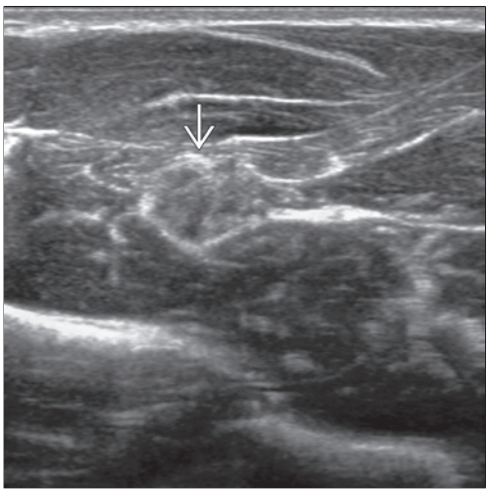


Nerve Injury

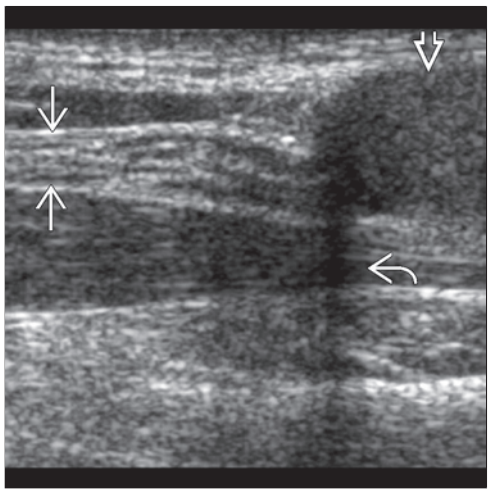


(Left) *Longitudinal ultrasound shows the median nerve ➔ following a dog bite. The nerve is mildly swollen with injury to the more superficial part. The deep fascicles are intact ➔. The overlying soft tissues are also swollen ➔.* ***(Right)*** *Transverse ultrasound shows a thick band of fibrosis ➔ surrounding a swollen radial nerve ➔ following severe trauma to the posterolateral aspect of the distal arm many years previously. Mild cortical irregularity of the distal humerus is still present ➔.*

Perineural Fibrosis

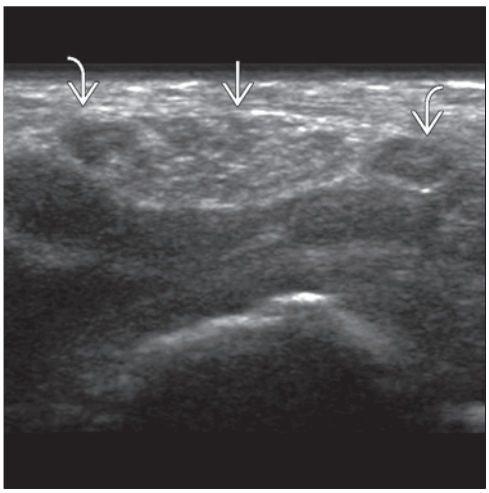


Perineural Fibrosis

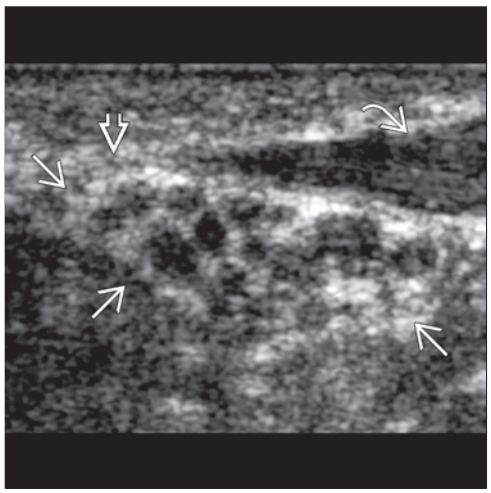


(Left) *Transverse ultrasound shows marked swelling of the medial nerve ➔ in the midforearm due to postsurgical fibrosis following previous resection of schwannoma.* ***(Right)*** *Longitudinal ultrasound shows a neuroma ➔ at the distal end of the transected medial nerve ➔. Note edge shadowing at the proximal end of the neuroma ➔. Neuromas can occur after complete or incomplete nerve transection.*

Intraneural Lipoma

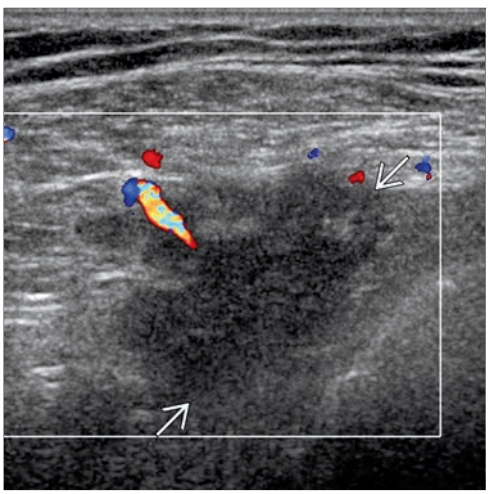


Fibrolipomatous Hamartoma

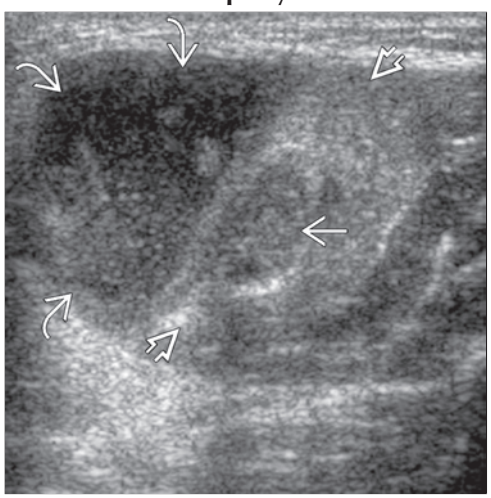


(Left) *Transverse ultrasound of the wrist shows a hyperechoic lipoma ➔ located between both components of the bifid median nerve ➔.* ***(Right)*** *Transverse ultrasound of the carpal tunnel inlet in a patient with middle finger macrodactyly shows a severely thickened median nerve (56 mm²) ➔ with thickened hypoechoic nerve fascicles. Note the hypothenar eminence ➔ and flexor retinaculum ➔. Fibrolipomatous hamartoma has a predilection for the median nerve.*

Metastases



Leprosy



(Left) *Transverse color Doppler ultrasound of supraclavicular region shows metastatic infiltration ➔ obscuring the brachial plexus in a patient with known breast carcinoma. Fine-needle aspiration confirmed metastatic infiltration.* ***(Right)*** *Transverse ultrasound proximal to the elbow shows a thickened ulnar nerve ➔ with marked surrounding edema, echogenic granulation tissue ➔, and abscess ➔ due to leprosy. Perineural abscess is an uncommon feature of leprosy. (Courtesy S. Lodge, MD.)*

FASCIAL LESION

DIFFERENTIAL DIAGNOSIS

Common
- Plantar Fasciitis
- Plantar Fibromatosis

Less Common
- Plantar Fascial Tear
- Enthesopathic Fasciitis
- Investing Fascial Tear
- Nodular Fasciitis
- Infective Fasciitis
- Necrotizing Fasciitis
- Eosinophilic Fasciitis
- Dupuytren Disease
- Tumors Occurring Within Fascia

ESSENTIAL INFORMATION

Key Differential Diagnosis Issues
- Plantar fascia seen as thin, laminated, echogenic aponeurosis stretching between calcaneus and forefoot
  - 2 bands: Larger medial and smaller lateral band
- Investing fascia seen as thin, laminated, echogenic tissue enveloping muscles of appendicular skeleton and trunk
- Fascial lesions tend to be site specific
- For most lesions, US is as accurate as MR or CT
- Fascial insertional lesions may be first manifestation of inflammatory enthesopathy

Helpful Clues for Common Diagnoses
- **Plantar Fasciitis**
  - Probably caused by repetitive microtrauma ± microvascular injury
  - Common in runners
    - Other risk factors include faulty shoes, high-arched feet, short Achilles tendon, obesity, and prolonged weightbearing
  - Affects plantar fascial attachment to medial aspect of calcaneus
    - Bilateral in 1/3 patients
  - Manifested as thickening of plantar fascia at calcaneal insertion
  - > 4.3 mm thickness considered abnormal
    - Hypoechogenicity and thickening of plantar fascia over short segment (~ 10 mm) at calcaneal insertion
    - ± loss of echogenic laminar pattern of plantar fascia
    - ± perifascial edema
    - 4.3 mm = guideline only; no absolute measurement as range of thickness of plantar fascia in affected patients and unaffected subjects overlaps
    - Measurements taken at leading edge of calcaneus
    - The greater the plantar fascial thickening, the more likely diagnosis of plantar fasciitis
    - Subclinical fascitis may be present on opposite side; therefore, exercise caution in using contralateral side as normal reference
  - ± plantar calcaneal spur
    - Echogenic bony spur ~ 1-3 mm long at deep surface of plantar fascia
  - Small foci of dystropic calcification as well as small intrafascial tears can sometimes be seen in thickened fascia at calcaneal insertion
  - ± edema, reduced lobulation, thinning, or early fibrosis of overlying subcutaneous heel fat pad
  - Minimal focal hyperemia in < 10% of patients with plantar fasciitis
  - Associated calcaneal bone marrow edema ± inflammation at plantar fascial insertional area not visible with US
    - Best seen with MR; however, not known to be useful prognostic indicator
  - Many different treatments
    - Stretching
    - Massage (e.g., rolling tennis ball under affected area)
    - Orthosis, night splints
    - US-guided steroid injection
    - US-guided platelet-rich plasma injection
    - Low level laser therapy
    - Combined cryo-ultrasound therapy
    - Extracorporal shockwave therapy
    - Radiofrequency ablation of calcaneal branches of inferior calcaneal nerve
    - US-assisted partial plantar fascial release
    - 23-gauge needle to edge of plantar fascia medially
    - Do not inject directly into plantar fascia; inject to perifascial area
- **Plantar Fibromatosis**
  - Focal nodular fibroblastic proliferation of plantar fascia away from calcaneal insertion
    - No specific risk factors identified
  - Most commonly affects medial band of plantar fascia in midfoot region
    - Often multiple
    - Bilateral in 1/3 of patients
  - Discrete fusiform-shaded nodule expanding plantar fascia
    - Either hypoechoic (75%) or isoechoic (25%) to plantar fascia
  - Long axis of fibroma usually aligned with long axis of plantar fascia band
  - Posterior acoustic enhancement (20%)
  - Internal vascularity (10%)
  - Calcification or visible tears not a feature
  - Does not infiltrate beyond plantar fascia
    - If present, consider aggressive plantar fibromatosis

Helpful Clues for Less Common Diagnoses
- **Plantar Fascial Tear**
  - May be acute or chronic
    - Localized and does not extend across width of plantar fascia
  - Acute tears are usually precipitated by specific traumatic event
    - May be precipitated by steroid injection for plantar fasciitis
  - More common on medial side
  - Involve proximal and middle 1/3 of plantar fascia equally
    - Involvement of forefoot region rare
  - Acute tears characterized by focal disruption of fascia, perifascial edema, and inflammation
  - Chronic tears characterized by focal disruption, tendon thickening, perifascial fibrosis, and hyperemia
- **Enthesopathic Fasciitis**

- Plantar fascia insertion is not uncommon site of involvement in enthesopathy
  - Medial plantar fascial band involvement at calcaneal insertion
  - Latera plantar fascial band insertion at base of 5th metatarsal bone
- Plantar fascial thickening, hyperemia with cortical irregularity, osteophytic spurs (enthesophytosis), and cortical erosions (entheseal erosions)
  - Specific sign of enthesopathy

• **Investing Fascial Tear**
- Investing fascia envelops muscles of appendicular skeleton and trunk
- Either complete focal defect in fascia or linear intrasubstance fascial tear
- Focal defect may result in muscle hernia
  - Accentuated by muscle contraction
  - Often occurs spontaneously in athletic muscular individuals
  - Also often occurs near perforating vessel
- Linear tear follows specific injury to affected region

• **Nodular Fasciitis**
- Benign proliferation of fibroblasts and myofibroblasts of investing fascia
  - Lesions are generally small and solitary
  - Most commonly involves upper limb
  - Patient may have history of preceding trauma, but usually no traumatic history and no known cause

• **Infective Fasciitis**
- Infection centered around investing fascia
  - No fulminant necrotic element present

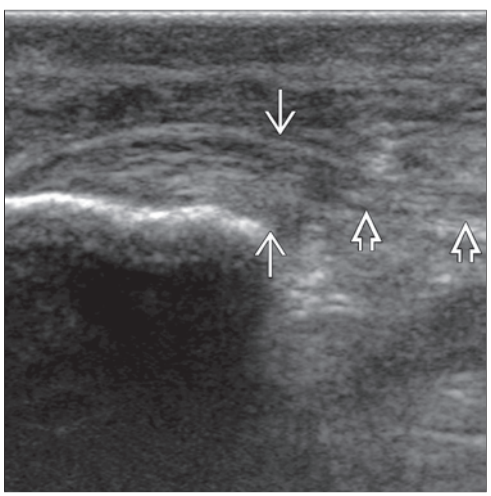
• **Necrotizing Fasciitis**
- Advancing soft tissue infection characterized by widespread fascial necrosis
- May occur after trauma or surgery
- Either monomicrobial or polymicrobial infection can cause necrotizing fasciitis
  - Group A β-hemolytic *Streptococcus* is a common causative organism
- Thickened disrupted fascia with perifascial fluid
- Severe subcutaneous and muscle edema
- ± muscle necrosis
- ± gas locules due to gas-forming organisms
- Known as Fournier gangrene as it affects external genitalia, perineal, or perianal regions

• **Eosinophilic Fasciitis**
- Disorder characterized by peripheral eosinophilia and fasciitis
  - Investing fascia and intermuscular fascia of forearm and calf are most commonly affected
- Thickening and hyperemia of muscle fascia on US
- Diagnostic MR appearances
  - Isolated fascial thickening, edema, inflammation in affected areas, and little or no myositis

• **Dupuytren Disease**
- Dupuytren disease is a fibroproliferative disorder of the palm of the hands leading to progressive permanent digital contracture
- Significant risk factors are old age, male sex, white northern European ancestry, positive family history of Dupuytren disease, and diabetes mellitus
- Disease deteriorates most rapidly in cases that show earlier age of onset
- Associated with fibromatosis affecting the back of hands, soles of feet, and penis
- Predominantly affects little, ring, and middle fingers
  - Generally starts as a small lump in the palm overlying metacarpophalangeal joint area (stage A)
  - Progressive fibrosis of palmar aponeurosis and fingers with fibrous-type cord becoming evident (stage B)
  - Fibrous cord-like extension from palm into fingers with progressive finger contracture (stage C)
- US generally useful only in stage A disease to ascertain nature of palmar lump
  - In stage B and C disease, diagnosis is clinically obvious and US is not beneficial
- Treatment involves either fasciotomy (simple division) of contracted fascia or limited fasciectomy

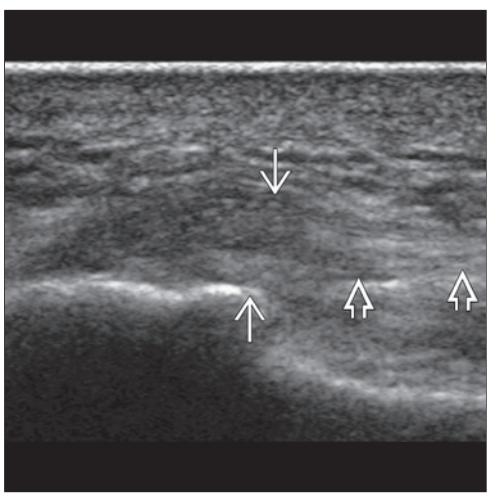
• **Tumors Occurring Within Fascia**
- Vascular malformations or lipoma may arise within or involve fascia
- Appearances akin to similar tumors arising beyond fascia

Plantar Fasciitis



Longitudinal US shows mild thickening (4.6 mm) ➔ of the plantar fascia ➔ at the anteromedial leading edge of the calcaneum (medial calcaneal tuberosity), consistent with mild plantar fasciitis.

Plantar Fasciitis



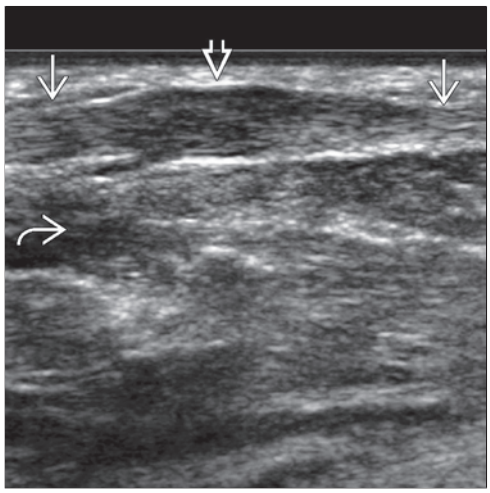
Longitudinal US shows moderate-severity (5.6 mm) thickening ➔ of the plantar fascia ➔ at the anteromedial leading edge of the calcaneum, consistent with moderate-severity plantar fasciitis.

FASCIAL LESION

Plantar Fibromatosis

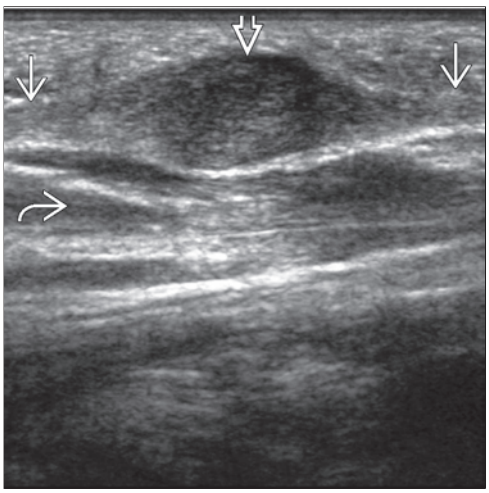


Plantar Fibromatosis

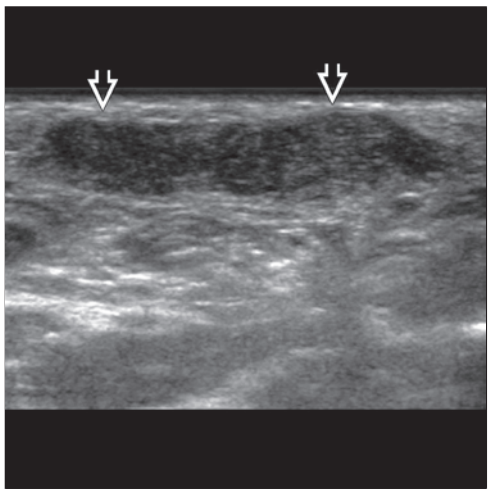


(Left) *Photograph shows a solitary plantar fibroma in the midfoot region.* ***(Right)*** *Longitudinal US in the same patient shows a fusiform-shaped swelling of the plantar fascia in the midfoot region consistent with a plantar fibroma (plantar fibromatosis). Minimal posterior acoustic enhancement is present. The underlying adductor digiti minimi muscle is normal.*

Plantar Fibromatosis

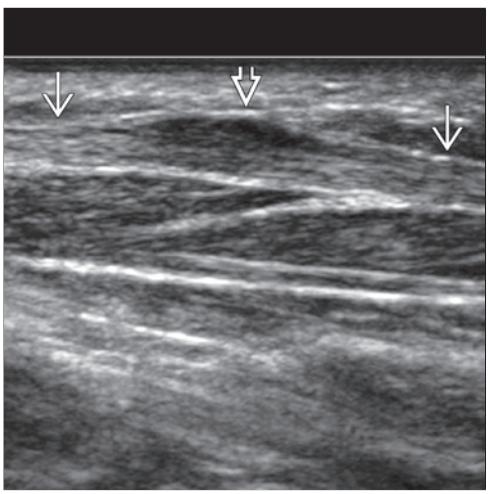


Plantar Fibromatosis

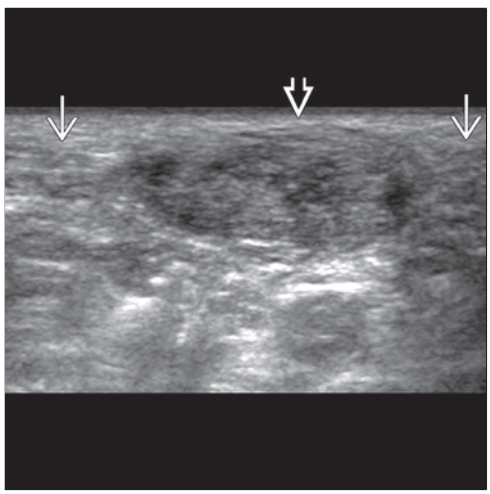


(Left) *Longitudinal US shows prominent localized fusiform thickening of the plantar fascia consistent with a plantar fibroma. This is an unusually thick plantar fibroma indenting the adductor digiti minimi muscle.* ***(Right)*** *Longitudinal US shows localized oblong-shaped thickening of the plantar fascia consistent with plantar fibroma (plantar fibromatosis). This is an unusually thickened, elongated plantar fibroma. Most plantar fibromas are smaller.*

Plantar Fibromatosis

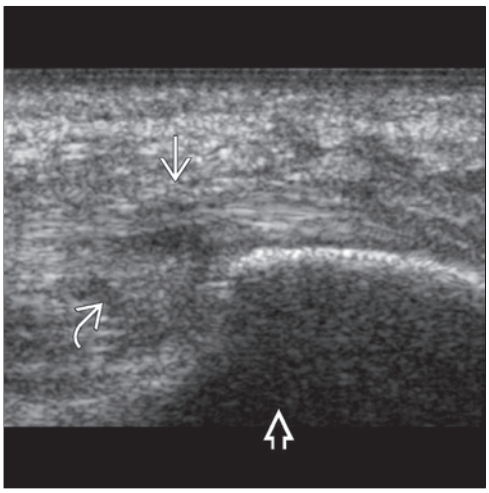


Plantar Fibromatosis

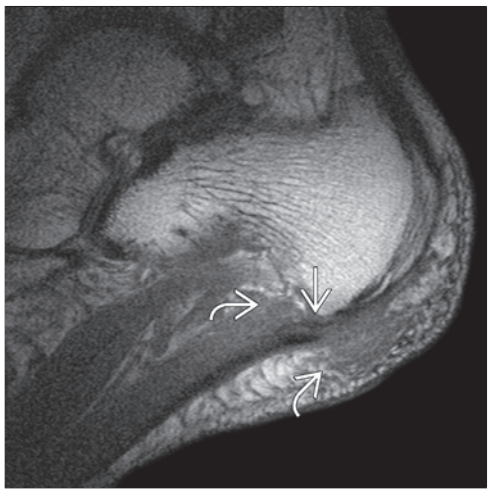


(Left) *Longitudinal US shows mild localized thickening of the more superficial aspect of the plantar fascia consistent with a small plantar fibroma. When only part of the plantar fascia is affected, it is usually the more superficial aspect.* ***(Right)*** *Longitudinal US shows an unusually echogenic plantar fibroma (plantar fibromatosis) present along the plantar fascia. Most plantar fibromas are hypoechoic though some are hyperechoic.*

Plantar Fascial Tear

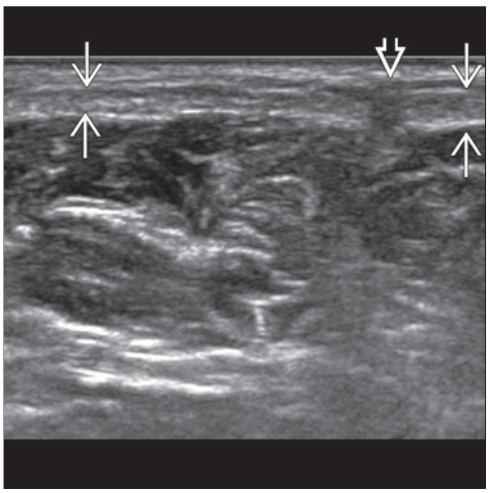


Plantar Fascial Tear

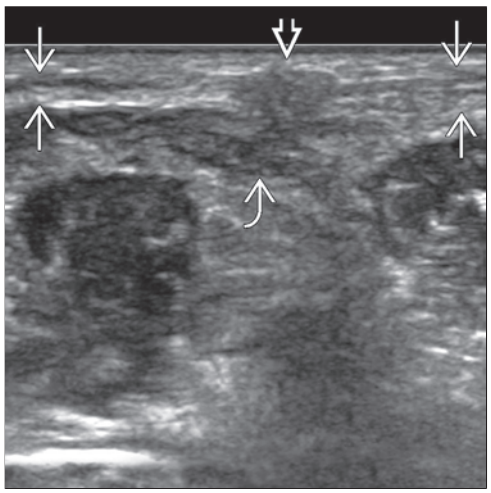


(Left) *Longitudinal US shows localized thinning of the plantar fascia ➡ immediately distal to the calcaneum ➡ due to a partial thickness tear. There is moderate perifascial edema ➡. The plantar fascia is not thickened, i.e., there is no plantar fasciitis present.* ***(Right)*** *Sagittal T1WI MR in the same patient shows a plantar fascial tear ➡ just distal to the calcaneal insertion with surrounding fluid and edema ➡.*

Plantar Fascial Tear

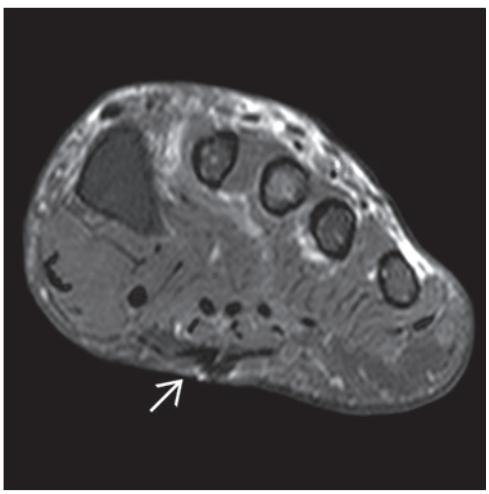


Plantar Fascial Tear

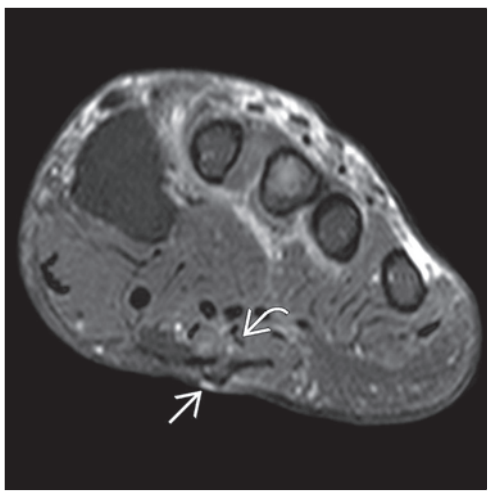


(Left) *Transverse US in a patient with localized trauma to the foot 3 months previously shows a slit-like tear ➡ with discontinuity of the plantar fascia ➡ in the midfoot region. The remaining plantar fascia is normal.* ***(Right)*** *Transverse US of the midfoot in the same patient just distal to the previous location shows the tear of the plantar fascia ➡ with herniation of part of the underlying flexor digitorum brevis muscle ➡ through this traumatic fascial defect ➡.*

Plantar Fascial Tear



Plantar Fascial Tear

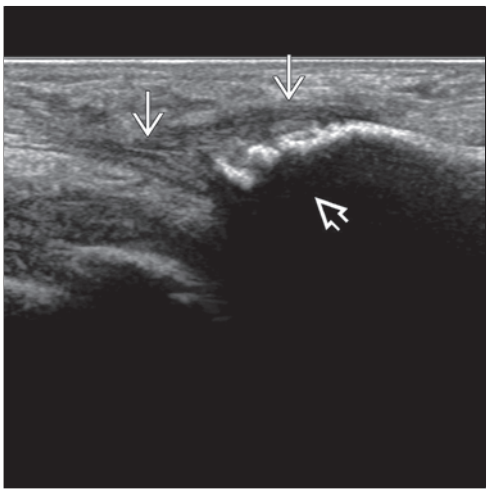


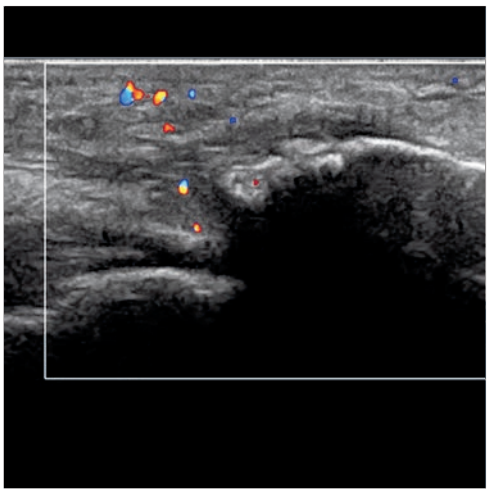
(Left) *Coronal T2WI FS MR in the same patient shows a slit-like tear in the plantar fascia ➡.* ***(Right)*** *Coronal T2WI FS MR of the same patient just distal to the previous image shows the tear of the plantar fascia with displacement of part of the flexor digitorum brevis muscle ➡ through this fascial defect ➡. There is only minimal edema of the affected muscle in keeping with this being a chronic injury.*

FASCIAL LESION

Enthesopathic Fasciitis

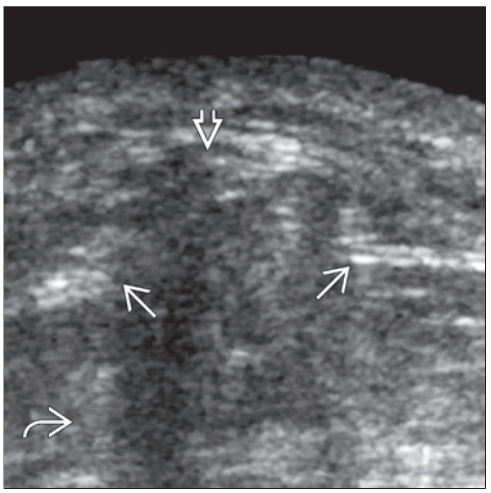
(Left) *Longitudinal US shows moderate cortical irregularity at the medial aspect of the 5th metatarsal base with thickening of the lateral band of the plantar fascia just proximal to its 5th metatarsal base insertion, consistent with enthesopathic fasciitis. There were other changes of enthesis elsewhere in the foot. The peroneus brevis insertion more laterally was normal.* ***(Right)*** *Longitudinal color Doppler US of the same patient shows mild localized hyperemia.*

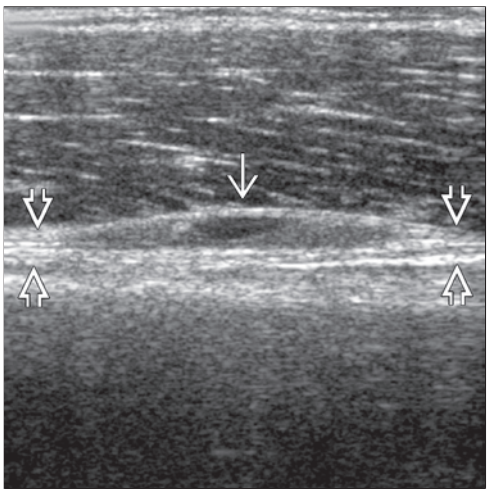




Investing Fascial Tear

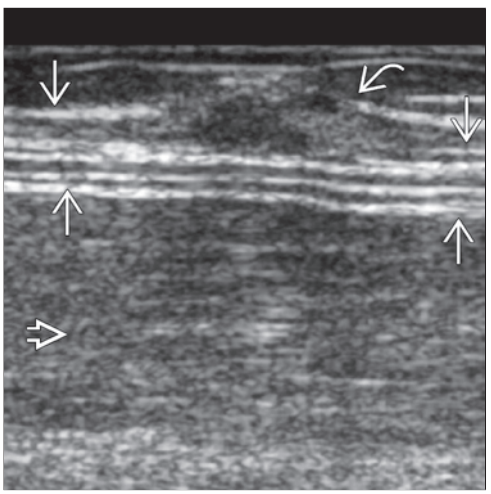
(Left) *Transverse US shows herniation of the peroneal muscle into the subcutaneous tissues though a defect in the investing fascia. This patient had point tenderness at this location aggravated by exercise.* ***(Right)*** *Longitudinal US shows an elongated tear within the substance of vastus medialis fascia of the thigh. The small hypoechoic area most likely represents fluid. This split-like intrasubstance fascial tear occurred during a fall while playing basketball.*



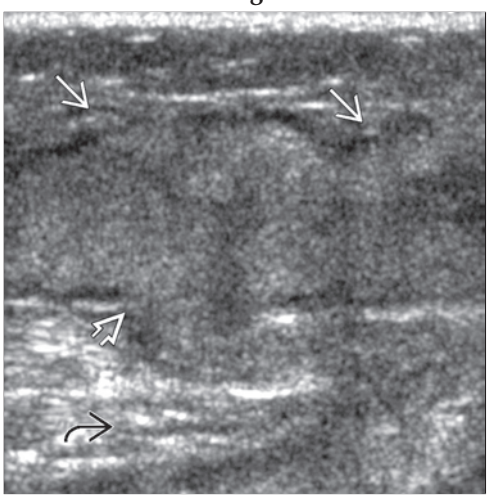


Nodular Fasciitis

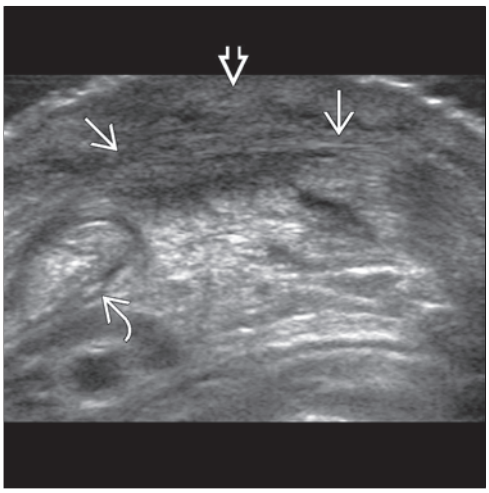
(Left) *Longitudinal US shows a small fibrotic-type mass within the superficial layers of the investing fascia of the arm in a young patient with no history of trauma. The underlying muscle is normal. The mass had completely resolved on follow-up 9 months later.* ***(Right)*** *Longitudinal US of the thigh shows a lobulated abscess extending through the investing fascia into the vastus lateralis muscle. Surgery confirmed necrotizing fasciitis.*



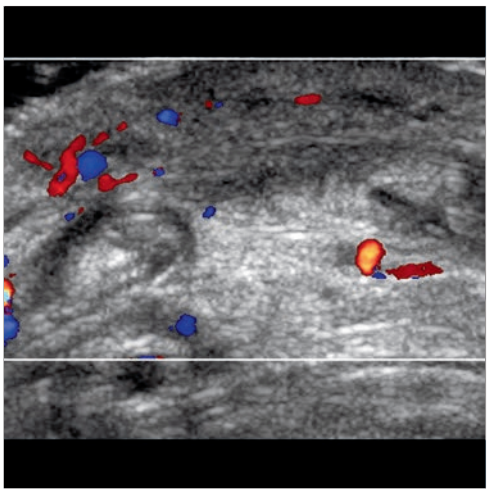
Necrotizing Fasciitis



Infective Fasciitis

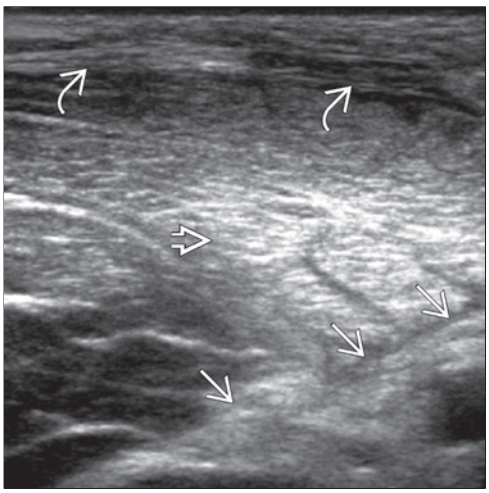


Infective Fasciitis

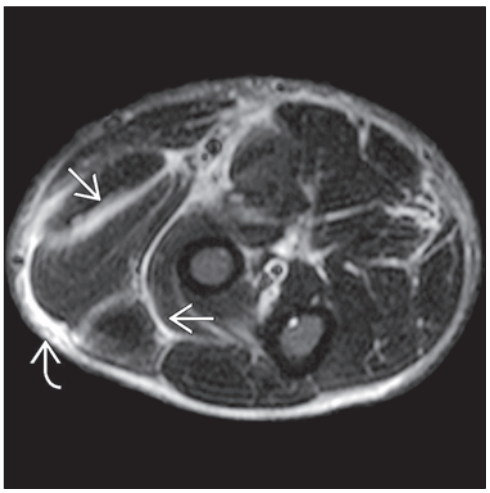


(Left) *Transverse US of the anterior ankle region shows moderate swelling and edema both superficial and deep to the investing fascia of the leg. No liquefaction is present. The tibialis anterior tendon is normal.* ***(Right)*** *Transverse color Doppler US in the same patient shows moderate surrounding hyperemia. Infective fasciitis is characterized by infection centered around the fascia. Not all infection around a fascia is necrotizing fasciitis.*

Eosinophilic Fasciitis

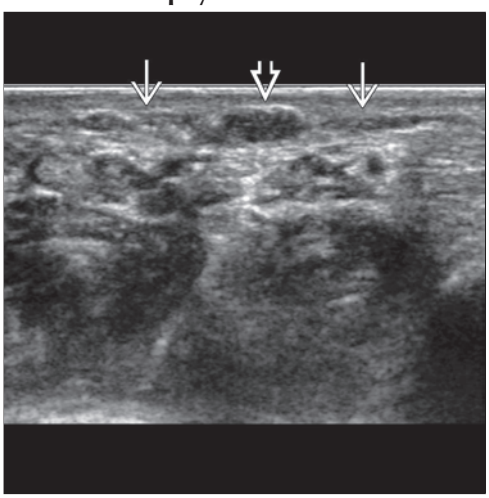


Eosinophilic Fasciitis

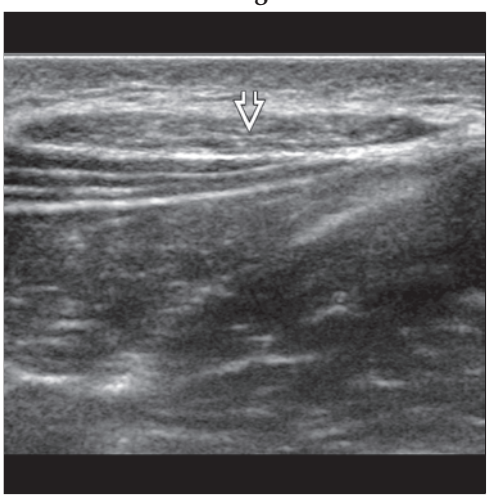


(Left) *Transverse US of the forearm shows thickening of the investing fascia and intermuscular fascia in a patient with eosinophilia. Echogenic muscle edema is also present.* ***(Right)*** *Transverse T2WI MR with fat suppression in the same patient shows edema and thickening of the investing fascia and intermuscular fascia. This is characteristic of eosinophilic fasciitis. Biopsy is generally not required.*

Dupuytren Disease



Tumors Occurring Within Fascia



(Left) *Transverse US of the palm in a patient with palmar nodule shows localized nodular hypoechoic thickening of the palmar aponeurosis. This is consistent with early Dupuytren disease. US is only indicated in early Dupuytren disease when there is a palmar nodule of uncertain etiology.* ***(Right)*** *Transverse US in patient with back swelling shows a thin intrafascial lipoma in the midlumbar region contained within the investing fascia.*

BONE SURFACE LESION

DIFFERENTIAL DIAGNOSIS

Common
- Osteochondroma
- Other Benign Bone Tumor
- Malignant Bone Tumor

Less Common
- Metastases
- Bone Tumor Recurrence
- Acute Osteomyelitis
- Chronic Osteomyelitis
- Fracture
- Orthopedic Implant
- Cortical Tug Lesion
- Juxtacortical Tumor

ESSENTIAL INFORMATION

Key Differential Diagnosis Issues
- Radiographs or other imaging very helpful when assessing bone surface lesions on ultrasound
- Ultrasound cannot assess intramedullary extent or surrounding bone quality
- Beware of normal bone irregularity at sites of muscle insertion and previous surgery
- Heavy calcification or ossification alongside bone may appear attached to bone on ultrasound
- Only portion of bony lesion visible with ultrasound
  - Angulation of transducer can help provide more comprehensive evaluation
  - MR or CT is often required for complete evaluation
- Determining etiology of surface bone lesions is often helped by clinical features
  - Age of patient
  - Location of lesion
  - Duration and type of symptoms
- Ultrasound-guided biopsy of bone tumor is possible if extraosseous mass is present
- Ultrasound-guided biopsy of intramedullary component of bone tumor or infection is possible via cortical breach if present

Helpful Clues for Common Diagnoses
- **Osteochondroma**
  - Most common bone surface tumor
  - Metaphyseal or metadiaphyseal in location
    - Points away from joint
  - Majority are solitary
    - If multiple and metaphyseal dysplasia indicates multiple hereditary exostoses (diaphyseal aclasis)
  - Variable thickness in hypoechoic cartilage cap
    - Often not visible or barely visible
    - Cap thickness of ≥ 2 cm is strongly indicative of secondary chondrosarcoma
    - Progressive thickening of cartilage cap on serial imaging is also indicative of chondrosarcoma
  - Most osteochondromas are asymptomatic
  - Symptoms can be due to several causes
  - Reactive myositis secondary to friction between osteochondroma and adjacent muscle
    - Degree of myositis is best evaluated on MR
  - Reactive bursitis
    - Friction between osteochondroma and muscle or tendon can lead to development of intervening adventitial bursa
  - Pseudoaneurysm
    - Most common vascular complication
    - Arterial rupture → arterial lumen contained by hematoma
    - Characteristic "to and fro" pattern on spectral analysis of narrow neck
    - Characteristic "yin-yang" bi-directional flow pattern on color Doppler imaging of lumen
  - Bleeding
    - From vascular injury, hemorrhagic bursitis, or myositis
  - Neurological sequelae
    - May cause compressive neuropathy, radiculopathy, or myelopathy depending on location
    - Snapping nerve → reactive neuritis
  - Fracture
    - Affects stalk of pedunculated osteochondroma
  - Malignant transformation more common with
    - Diaphyseal aclasis (likelihood ~ 1%)
    - Increase in age
    - Osteochondromas located in axial skeleton
- **Other Benign Bone Tumor**
  - Most intramedullary benign tumors remain intramedullary
    - May expand bone cortex or fracture → bone surface irregularity
  - Giant cell tumor of bone, not infrequently, has extraosseous soft tissue component
    - Hypervascular ± hemorrhagic cystic areas
  - Other benign juxtacortical tumors
    - Chondroma, fibroma, schwannoma
- **Malignant Bone Tumor**
  - Osteosarcoma is most common malignant bone tumor
    - Usually occurs in childhood or young adulthood
  - Arises most frequently at metaphyseal ends of long bones
    - Areas of most rapid growth in childhood
  - Hypoechoic, broad-based tumoral outgrowth from bone
  - Spiculated seams of tumoral osteoid deposition
  - Moderately hyperemic
  - Ultrasound-guided biopsy undertaken if significant extraosseous component
  - Intramedullary ultrasound-guided bone biopsy can be performed if cortical breach is present

Helpful Clues for Less Common Diagnoses
- **Metastases**
  - Can be detected by ultrasound if periosteal margin of cortex is affected
    - Purely medullary metastases are not seen by ultrasound
  - Lung and breast are most common primary sites
    - Adenocarcinoma is most common tumor cell type
  - Have predilections for diaphyseal location
  - Compromise bone strength as cortical bone is particularly relevant for diaphyseal bone strength
- **Bone Tumor Recurrence**
  - Ultrasound is very useful at screening for bone tumor recurrence
  - Based on knowledge that most bone tumor recurrences occur in juxtacortical soft tissues rather than in bone
  - Unlike MR, ultrasound assessment of juxtacortical soft tissues is not affected by metallic prosthesis

- Tumor recurrence usually mirrors imaging characteristics of original tumor
- If recurrence is detected, check regional lymph nodes as nodal involvement is more frequent with recurrence than with primary bone tumor

• **Acute Osteomyelitis**
- Most frequently involves metaphyses of long bones in children
- Fine lamellar periosteal reaction
- Anechoic fluid accumulation alongside cortex
- Subperiosteal accumulation of fluid
- Subperiosteal abscess
- Color Doppler imaging → hyperemia within and around inflamed periosteum
- ± concurrent septic arthritis
  - Sympathetic effusion is common
  - Septic arthritis can be excluded by aspiration
- Ultrasound-guided aspiration of subperiosteal fluid or abscess for Gram stain and culture
- MR is best at assessing acute osteomyelitis
  - Acute osteomyelitis is not excluded by normal ultrasound examination
  - Acute osteomyelitis is fully excluded by normal MR examination

• **Chronic Osteomyelitis**
- Most frequently involves diaphysis of long bones in young to middle-aged adults
- Coarse or fine periosteal reaction depending on level of activity
  - ± inflammatory cortical defect (cloaca)
  - ± sequestrum within extraosseous tissues
  - ± juxtacortical inflammation or abscess
  - ± sinus tract extending towards skin
- MR best at assessing activity and extent of chronic osteomyelitis
  - Ultrasound cannot evaluate intramedullary disease
  - Ultrasound is very helpful if metal implant in situ, which limits assessment by CT or MR

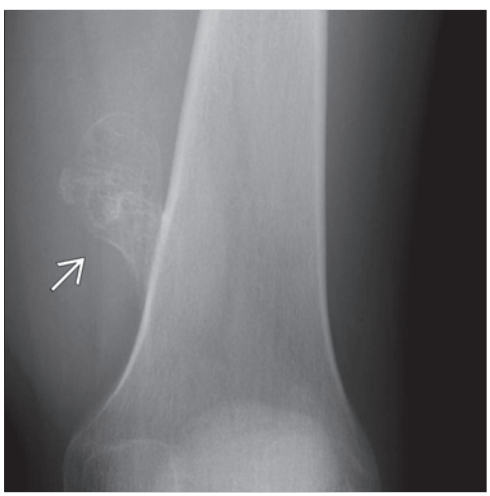
• **Fracture**
- 4 types of fracture
  - Traumatic, stress, insufficiency, and pathological
- Ultrasound is very useful in detecting most radiographically occult traumatic fractures provided affected bone is assessable to ultrasound
  - Also useful in other types of fracture though not as sensitive as in traumatic fractures
- Acute traumatic fracture
  - Focal cortical disruption
  - ± shadowing artifact (quite common) or reverberation artifact ("light house" or "chimney" phenomenon) (uncommon) at fracture site
  - Juxtacortical soft tissue swelling, edema, or hematoma (common)
- Healing traumatic fracture
  - Hypoechoic callus bridging fracture site with progressive ossification

• **Orthopedic Implant**
- Plate and screw fixation, bone-allograft anastomosis etc. can all give rise to suspicious bone surface appearance on ultrasound
  - Can mimic localized cortical bone destruction from tumor or infection
- Correlation with radiography will help to sort out in most cases
- If still in doubt, follow-up ultrasound in 2-4 weeks

• **Cortical Tug Lesion**
- Cortical hyperostosis at site where strong muscle is attached to bone
- Usually seen at site of attachment of gluteus maximus tendon into femoral shaft
- May cause both pain and increased activity on isotope bone scanning
- Do not confuse with more sinister pathology

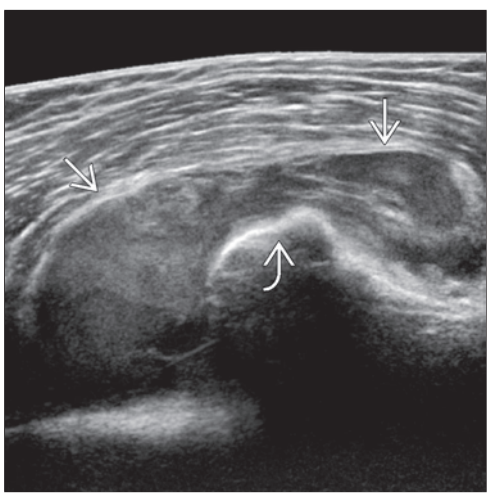
• **Juxtacortical Tumor**
- Soft tissue masses commonly lie against bone, i.e., occur in juxtacortical location
  - Examples include gouty tophus, vascular malformation, nerve sheath tumor, lipoma, etc.
- Hard tissue masses also less frequently occur in juxtacortical (periosteal) location
  - Examples include chondroma, chondromyxoid fibroma, periosteal osteosarcoma, or periosteal chondrosarcoma

Osteochondroma



Anteroposterior radiograph shows a large, pedunculated osteochondroma ➔ on the medial side of the distal femoral metaphysis. This lesion was symptomatic and referred for ultrasound examination.

Osteochondroma



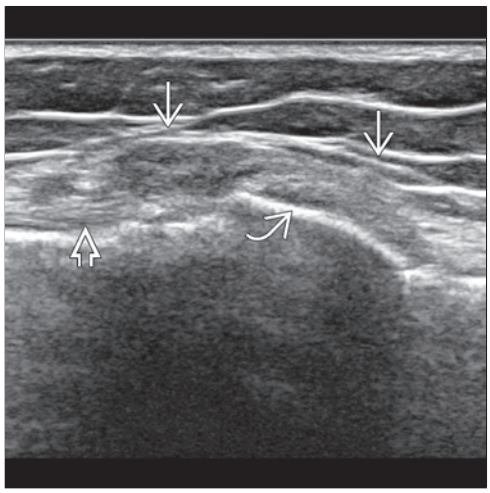
Longitudinal US of the same lesion as previous image shows bursa distended with hemorrhage ➔ overlying the osteochondroma ➔.

BONE SURFACE LESION

Osteochondroma

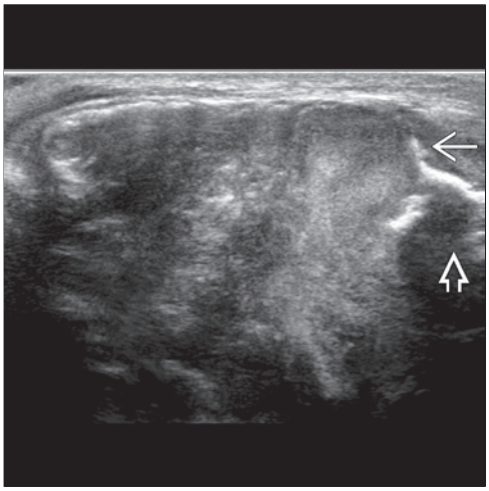


Osteochondroma

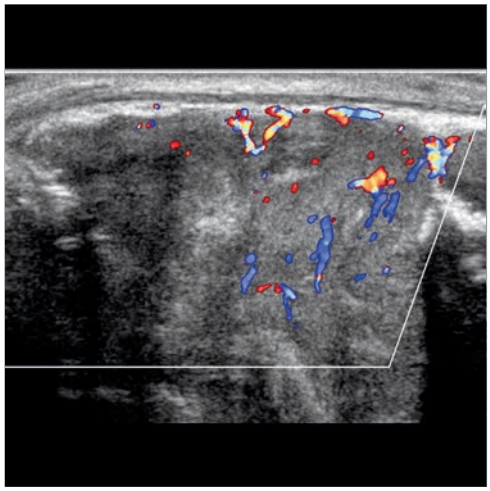


(Left) *Anteroposterior radiograph shows a small, symptomatic sessile osteochondroma on the medial aspect of the proximal tibial metaphysis.* ***(Right)*** *Longitudinal ultrasound of the same lesion shows a thick-walled chronic bursitis overlying this osteochondroma. The medial collateral ligament is seen proximally. The very thin hypoechoic layer is due to a thin cartilage cap. Bursa tend to develop in sites of chronic friction. They are lined by synovium.*

Other Benign Bone Tumor

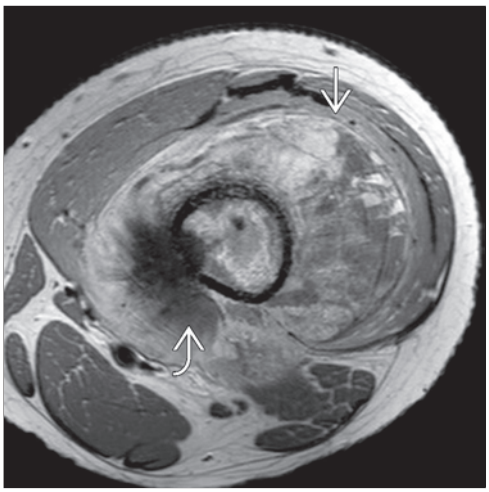


Other Benign Bone Tumor

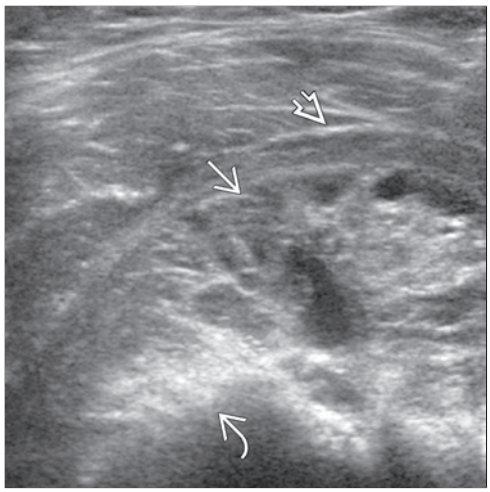


(Left) *Longitudinal ultrasound in a patient with foot pain and swelling for 12 months shows a large, expansile characteristically quite hypoechoic tumor elevating and thinning the cortex of the 1st metatarsal bone.* ***(Right)*** *Longitudinal color Doppler ultrasound of the same tumor shows moderate tumoral vascularity. Overall, appearances favor a giant cell tumor of the 1st metatarsal bone, which was confirmed by ultrasound-guided biopsy for histology.*

Malignant Bone Tumor

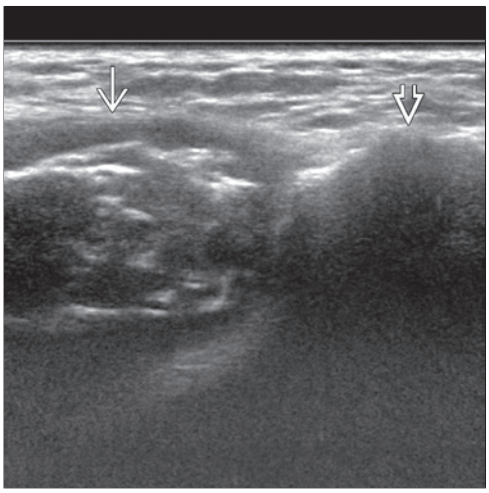


Malignant Bone Tumor

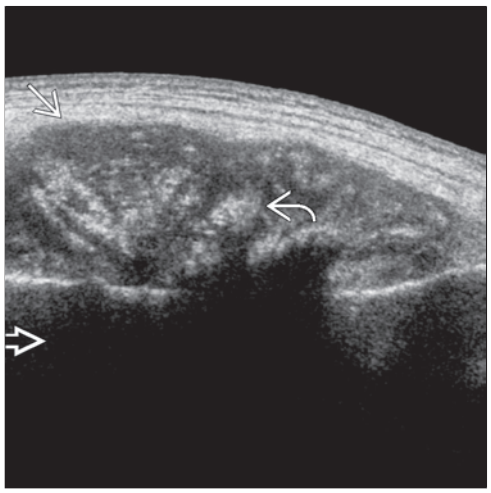


(Left) *Axial PD FSE MR of femur shows a bone tumor with a large, extraosseous, soft tissue component tumor anteromedially with fluid-fluid levels and dense, spiculated tumoral new bone formation posterolaterally.* ***(Right)*** *Transverse ultrasound of the anteromedial aspect of the same tumor showing dense, spiculated new bone formation posterolaterally and a large extraosseous soft tissue component displacing the vastus medialis muscle anteriorly. US-guided biopsy confirmed osteosarcoma.*

Malignant Bone Tumor

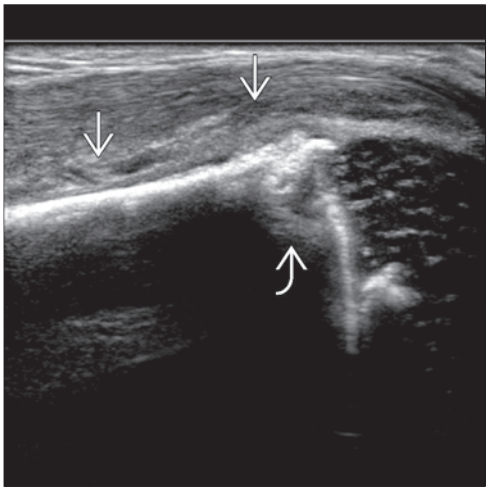


Malignant Bone Tumor

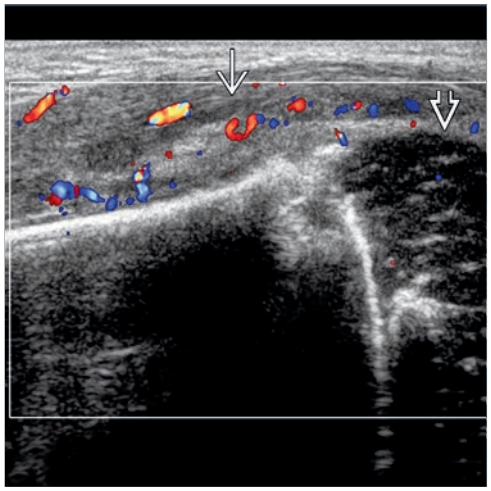


(Left) *Transverse ultrasound in a patient with treated breast carcinoma shows a hypoechoic tumoral rim around the lateral end of the clavicle* ➔ *with underlying osteolysis cortical thinning and irregularity. This was due to a radiation-induced sarcoma. The manubrium* ➔ *is normal.* ***(Right)*** *Longitudinal ultrasound shows a large, hypoechoic osteosarcoma* ➔ *arising from the distal femur* ➔*. Note the spiculated echogenic seams* ➔ *of mineralized osteoid within the extraosseous tumor matrix.*

Acute Osteomyelitis

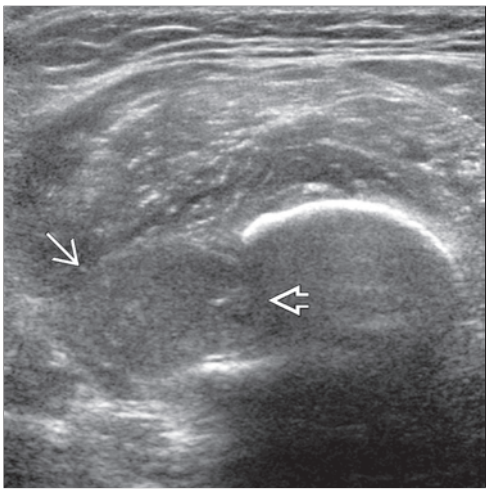


Acute Osteomyelitis

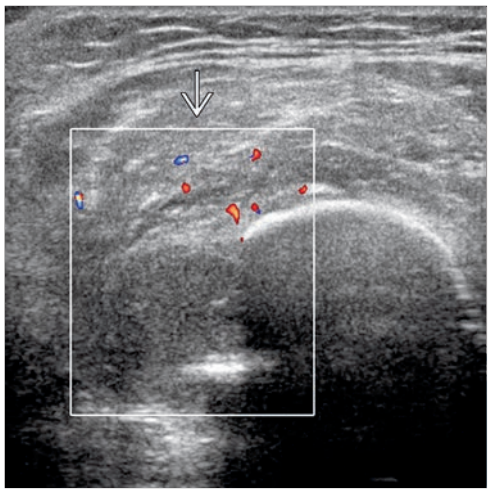


(Left) *Longitudinal ultrasound of a neonate with acute osteomyelitis of the femur shows focal cortical irregularity* ➔ *at the distal femoral metaphysis. This is associated with moderate periosteal soft tissue thickening and a small amount of subperiosteal fluid* ➔*.* ***(Right)*** *Longitudinal color Doppler ultrasound of the same patient shows moderate hyperemia of the thickened periosteal tissues* ➔*. The physis and epiphysis* ➔ *are normal.*

Chronic Osteomyelitis



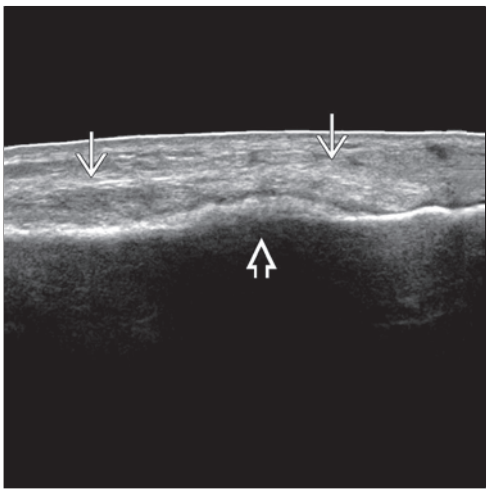
Chronic Osteomyelitis



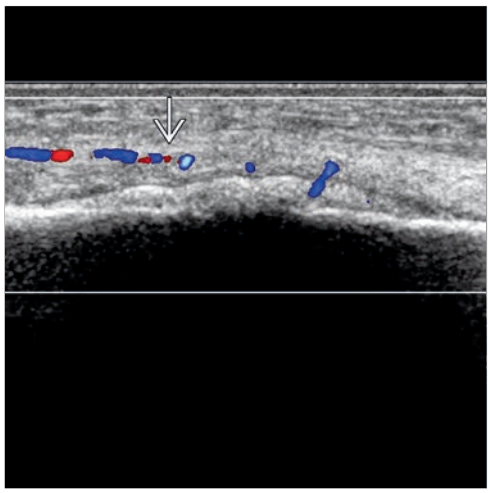
(Left) *Transverse ultrasound in a patient with acute exacerbation of chronic osteomyelitis shows an echogenic fluid collection* ➔ *alongside a large cortical defect* ➔ *on the medial side of the distal femoral cortex.* ***(Right)*** *Transverse color Doppler ultrasound of the same patient shows mild hyperemia* ➔ *of the inflamed adjacent soft tissues. Ultrasound-guided aspiration of the juxtacortical collection yielded Staphylococcus aureus.*

BONE SURFACE LESION

Fracture

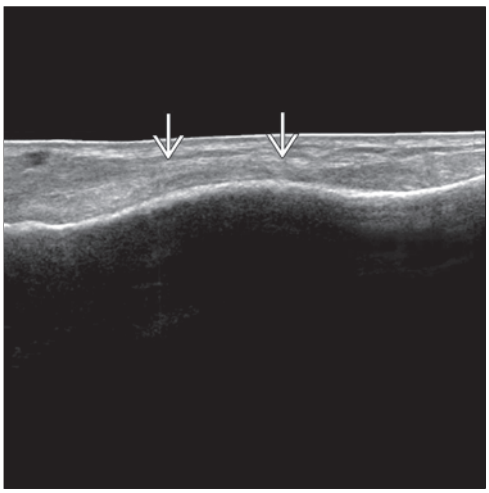


Fracture

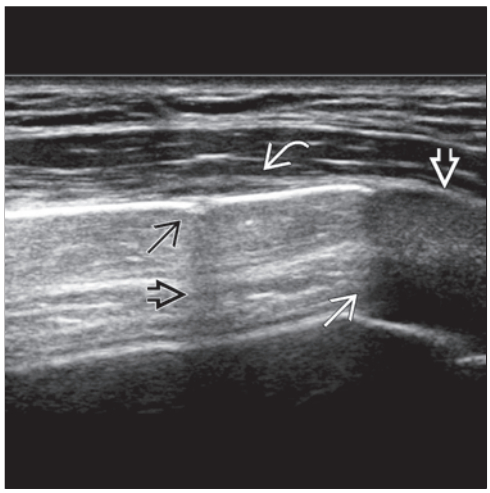


(Left) *Extended field-of-view ultrasound in a patient with foot pain shows an active stress fracture of the 2nd metatarsal bone with midshaft cortical hyperostosis and moderate surrounding soft tissue edema and swelling. **(Right)** Longitudinal color Doppler ultrasound of the same area shows moderate hyperemia of the soft tissues around the stress fracture.*

Fracture

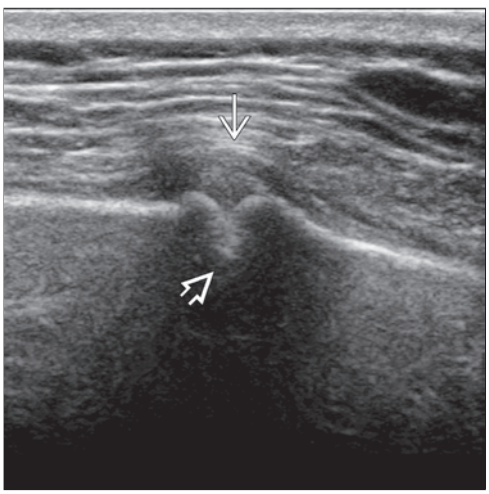


Fracture



(Left) *Extended field-of-view ultrasound shows a healed stress fracture of the 2nd metatarsal bone. There is a smooth cortical thickening of the metatarsal shaft with no inflammation or edema of the adjacent soft tissues. **(Right)** Longitudinal ultrasound shows an undisplaced fracture of the anterior cortex of a rib with mild acoustic shadowing artifact and a small adjacent hematoma. The hypoechoic costal cartilage and costochondral junction are shown.*

Fracture

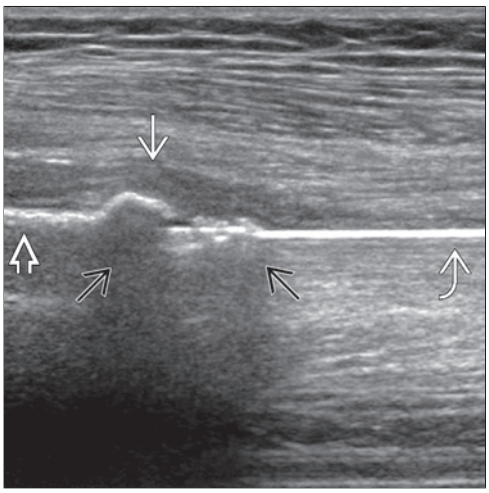


Fracture

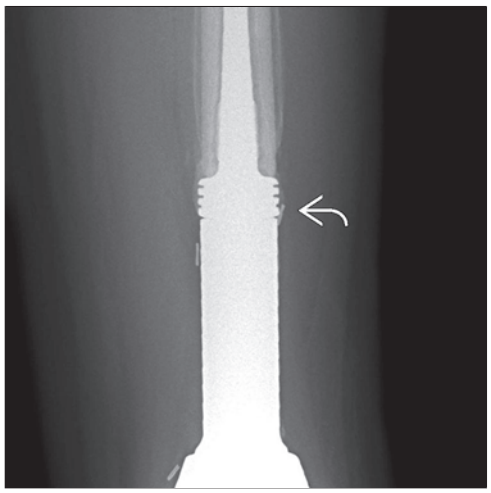


(Left) *Longitudinal ultrasound shows a healing rib fracture with a large amount of mildly mineralized hypoechoic callus bridging the fracture site. **(Right)** Longitudinal ultrasound shows a pathological fracture due to a hypoechoic metastasis from lung carcinoma infiltrating a rib. The metastatic deposit provides an acoustic window to view the underlying pleura.*

Orthopedic Implant

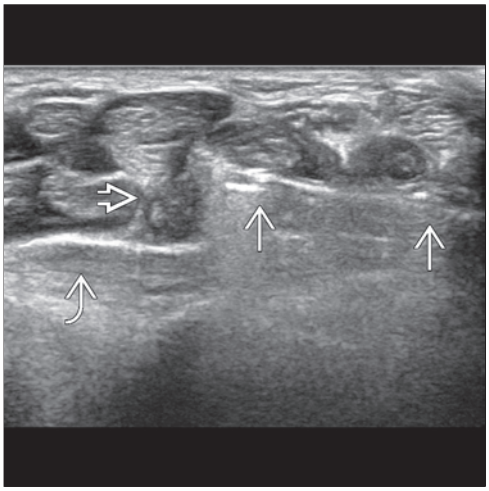


Orthopedic Implant

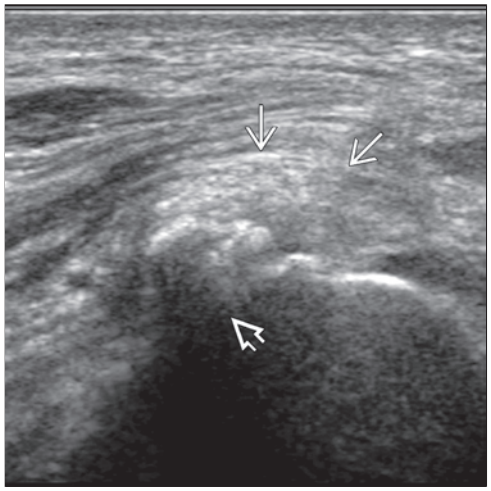


(Left) *Longitudinal ultrasound of a patient with an orthopedic implant shows mild reactive new bone formation ⇨ with soft tissue swelling thickening ➔ at the interface between the prosthesis ➔ and the bone ➔. **(Right)** Frontal radiograph of the same patient provides explanation of ultrasound findings, which are due to reactive new bone formation at the bone:prosthesis interface ➔. There is no evidence of tumor recurrence or infection.*

Orthopedic Implant

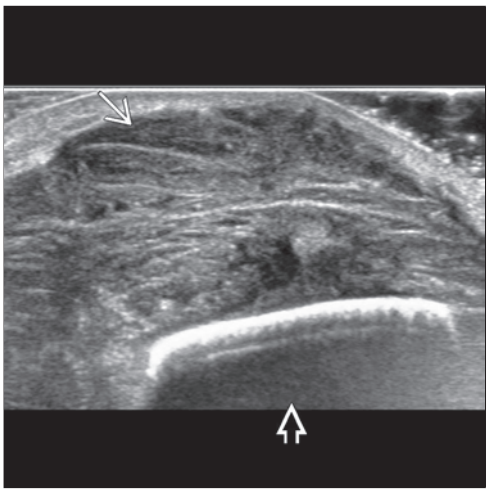


Cortical Tug Lesion

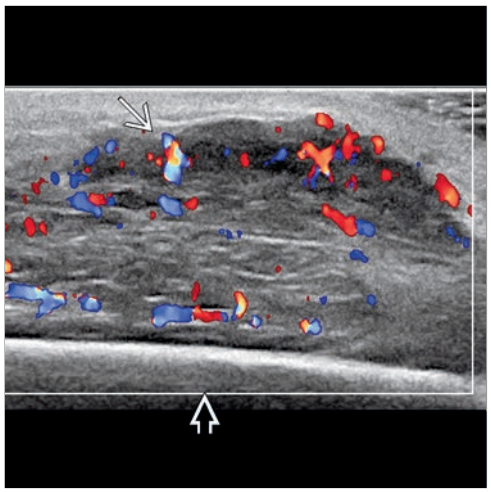


(Left) *Transverse ultrasound in a patient shows the medial end of a transverse fixation plate ➔ impinging onto the flexor digitorum profundus myotendinous junction ➔. Repeated friction between the tendon and the fixation plate may well lead to tendon attrition and rupture. The radius ➔ is normal. **(Right)** Transverse ultrasound shows localized cortical hyperostosis (tug lesion) ➔ on the posterolateral aspect of the femoral shaft due to insertion of the gluteus maximus tendon ➔.*

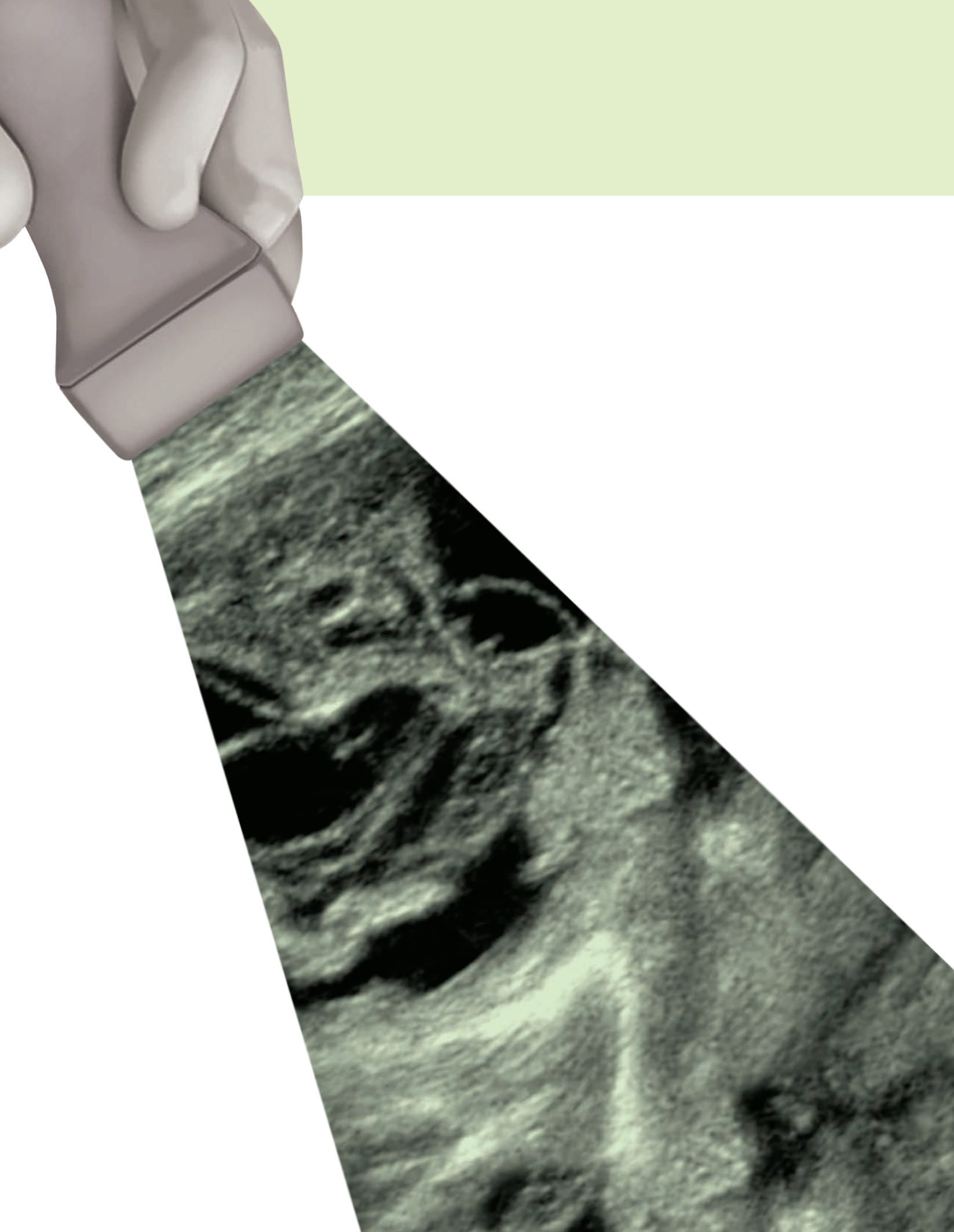
Juxtacortical Tumor



Juxtacortical Tumor



(Left) *Transverse ultrasound shows a large pretibial ➔ hypoechoic soft tissue mass ➔. Biopsy revealed non-Hodgkin lymphoma (follicular). Although the tibial cortex seems intact, subsequent MR revealed intramedullary extension. **(Right)** Longitudinal color Doppler ultrasound of the same mass shows moderate tumoral hyperemia ➔. The tibial cortex seems intact ➔. Most musculoskeletal lymphoma involves either bone or muscle.*



SECTION 4

Joint Abnormalities

Paraarticular Cystic Mass **III**-4-2
Synovial Swelling **III**-4-8
Joint Effusion **III**-4-14

PARAARTICULAR CYSTIC MASS

DIFFERENTIAL DIAGNOSIS

Common
- Ganglion Cyst
- Baker Cyst
- Parameniscal Cyst
- Bursal Distension
- Collection or Hematoma

Less Common
- Cystic-Looking Soft Tissue Tumor

ESSENTIAL INFORMATION

Key Differential Diagnosis Issues
- Establish whether mass is intra- or extracapsular
  - If extracapsular, does mass communicate with joint?
  - Where does mass communicate with joint?
  - Does it attach to labrum or meniscus or does it communicate with other part of joint ?
  - Sometimes direct continuity with joint is not visible but mass can be seen pointing towards joint
    - Additional imaging, with MR in particular, may sometimes be helpful in showing joint communication if ultrasound findings are equivocal

Helpful Clues for Common Diagnoses
- **Ganglion Cyst**
  - Mucinous fluid contained within fibrous pseudocapsule
    - Not lined by synovial tissue
  - Results from extruded synovial fluid
    - Joint pathology (e.g., synovitis) can occur within ganglia, but is uncommon due to closed or limited communication
  - Most common in hands and feet
    - 80% of soft tissue masses of hands and feet
    - Dorsal wrist ganglia are more commonly symptomatic, although volar wrist ganglia are overall more common
    - Most volar wrist ganglia are asymptomatic
  - Typical locations reflect weakness in joint capsule
    - Dorsal radiocarpal joint
    - Dorsal scapholunate joint
    - Scapho-trapezio-capitate joint
  - Near A1 pulley on middle, index, and ring fingers
    - Does not appear to communicate with metacarpophalangeal joint or flexor tendon sheath
  - Anechoic, well-defined, rounded or irregular mass alongside joint
    - ± "comet tail" artifacts due to aggregates of colloid material
    - Infrequently hyperechoic, due to hemorrhage or inflammatory content from joint
  - Typically has neck pointing toward particular joint
    - Usually neck cannot be traced to joint because it is too small
    - Important to identify potential joint of origin as it has therapeutic implications
  - About 1/2 of ganglia recur after percutaneous aspiration
    - Not possible to determine viscosity of content on grayscale appearances alone
    - Aspiration may be painful for 24-36 hours since content of ganglion cyst irritates soft tissues around ganglion
    - Hyaluronidase may facilitate aspiration by making contents less viscous
- **Baker Cyst**
  - Semimembranous-gastrocnemius bursa, which communicates with joint
    - Slit-like opening in capsule close to root of posterior horn medial meniscus
  - Classic "talk-bubble" configuration on transverse US with beak of bubble emerging between semimembranous tendon and medial head gastrocnemius muscle
    - Frequently bilateral
  - Usually extends distally over medial belly gastrocnemius muscle
    - Less commonly spreads proximally alongside semimembranous muscle
    - Uncommonly spreads into semimembranous or gastrocnemius muscle
  - Has synovial membrane and is therefore affected by synovial inflammatory or neoplastic disorders (e.g., PVNS) involving knee joint
    - Calcified bodies may occur in Baker cyst
  - Prone to either hemorrhage or leakage
    - Important to note as may make Baker cyst symptomatic
  - Hemorrhage
    - Fine echoes within cyst
    - Increased echogenicity of cyst fluid
  - Leakage or rupture
    - Angulated arrow-like, rather than rounded, configuration of cyst
    - Free fluid around margin of cyst
    - ± pericystic swelling and hyperemia
- **Parameniscal Cyst**
  - Cystic mass extending from peripheral aspect of meniscus
  - Usually associated with horizontal meniscal tear
    - Mucinous content (from synovial fluid or myxoid meniscal degeneration) expressed as perimeniscal cyst
  - Occasionally no meniscal tear is present
    - Meniscal tear may have healed
    - Cyst may have arisen from myxoid meniscal matrix in absence of tear
    - Cyst may have arisen from synovial fluid expressed not through meniscus but instead via tear in meniscocapsular ligament
  - Percutaneous cyst aspiration is helpful particularly in cases without any apparent meniscal tear
- **Bursal Distension**
  - 2 types of bursae
  - Synovial bursae: Synovial-lined bursa, which occurs at defined anatomical locations
    - Can be prone to synovial disorders such as synovitis or synovial osteochondromatosis
  - Adventitial bursae: Non-synovial-lined bursae acquired due to friction between opposing structures
  - Some paraarticular bursa more prone to bursitis than others
  - Subacromial-subdeltoid bursa
    - Fixed attachments to free edge of coracoacromial ligament and to greater tuberosity distal to attachment of supraspinatus and infraspinatus
    - Coracoid and proximal humeral recesses
    - Richly innervated
    - Most, if not all, pain from rotator cuff injury comes from subacromial-subdeltoid bursa

- Hence, pain is poorly localized
- If present, look closely for associated rotator cuff tear
- If markedly thickened bursa with hyperemia, consider inflammatory arthropathy (e.g., systemic lupus erythematous) or infection

○ Olecranon bursa
- Synovial bursa located between olecranon process and skin
- Composed of synovium and extrasynovial fat
- Common site of gouty bursitis
- Commonly inflamed, uncommonly infected

○ Iliopsoas bursa
- Synovial bursa located anterior to hip between iliopsoas tendon and hip capsule
- Communicates with hip joint in 15% of patients
- Consider iliopsoas infection, particularly tuberculous

○ Semimembranous bursa
- Synovial bursa between anterior arm of semimembranous tendon complex and medial collateral ligament
- Semimembranous tendon complex inserts to posteromedial corner of tibia
- Located medial to Baker cyst and proximal to pes anserinus bursa
- Distended bursa has J-shaped appearance

○ Pes anserinus bursa
- Pes anserinus = conjoint tendons of sartorius, gracilis, and semitendinous
- Insert into anteromedial aspect of tibia ~ 5 cm distal to knee joint
- Bursa located between pes anserinus and medial collateral ligament

○ Prepatellar, superficial, and deep infrapatellar bursae
- Prepatellar bursa located between patella and skin
- Superficial infrapatellar bursa located between tibial tuberosity and skin
- Deep infrapatellar bursa located between distal portion of patellar tendon and tibia, beneath Hoffa fat pad
- ≤ 3 mm deep distension of deep infrapatellar bursa common finding and considered normal

• **Collection or Hematoma**
○ Usually following surgery
○ Hematoma is solid looking when composed of clotted blood, undergoes progressive liquefaction
○ Collection may be anechoic or of variable echogenicity depending on content
○ Cannot determine infectivity based on echogenicity of content
○ Likelihood of infection increases with increasing degree of surrounding soft tissue swelling, edema, and hyperemia
○ US-guided aspiration if doubt exists
○ Aspiration also provides symptom relief with larger collections

Helpful Clues for Less Common Diagnoses

• **Cystic-Looking Soft Tissue Tumors**
○ Lymphangioma
- Lobulated, usually anechoic, no color flow

○ Vascular malformation
- Slow flow or high flow, variable stroma component

○ Cystic schwannoma
- Visible entering and exiting nerve

○ Myxoma
- Intramuscular, anechoic ± echogenic, colloid "comet tail" artifacts due to colloid aggregates

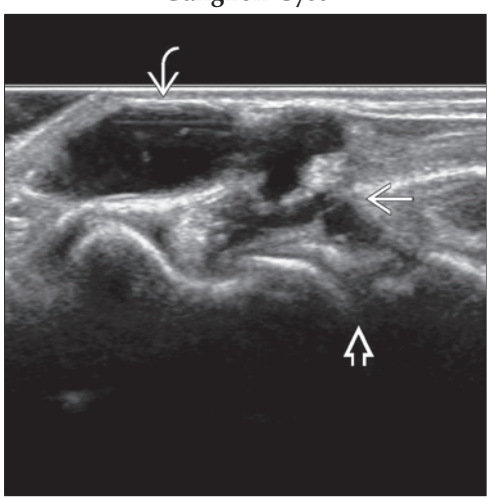
○ Epidermoid cyst
- Well-defined, encapsulated, subcutaneous, disc-like echogenic areas due to keratin aggregates, slit-like hypoechoic areas

○ Subcutaneous fat necrosis
- Fat trauma → fat inflammation → fat necrosis → liquefaction ± calcification

○ Cystic metastasis
○ Myxoid sarcoma
- Myoid liposarcoma
- Myxoid synovial sarcoma
- Fibromyxoid sarcoma

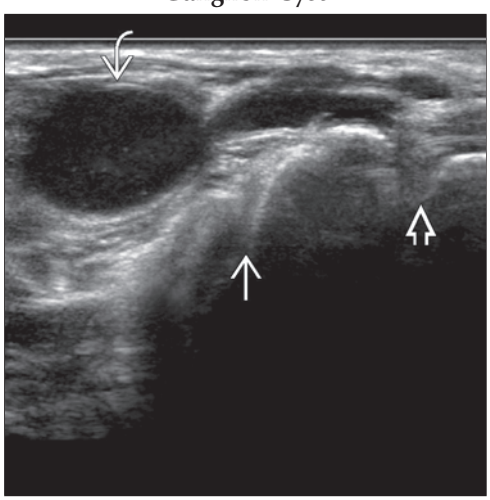
○ Venous varix
○ Aneurysm
○ Pseudoaneurysm

Ganglion Cyst



Longitudinal US shows medium-sized ganglion cyst with an irregular serpiginous tail extending to the dorsal aspect of the radioscaphoid articulation.

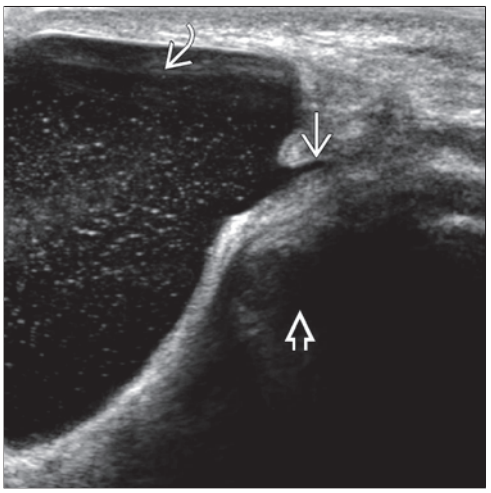
Ganglion Cyst



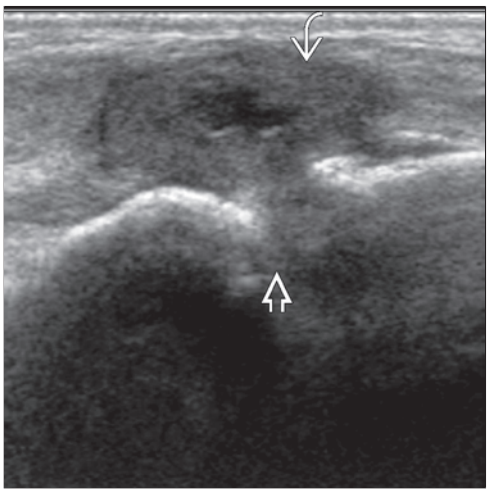
Longitudinal US shows a medium-sized ganglion cyst arising from the volar aspect of the scapho-trapezium articulation. The 1st carpo-metacarpal articulation is normal.

PARAARTICULAR CYSTIC MASS

Ganglion Cyst

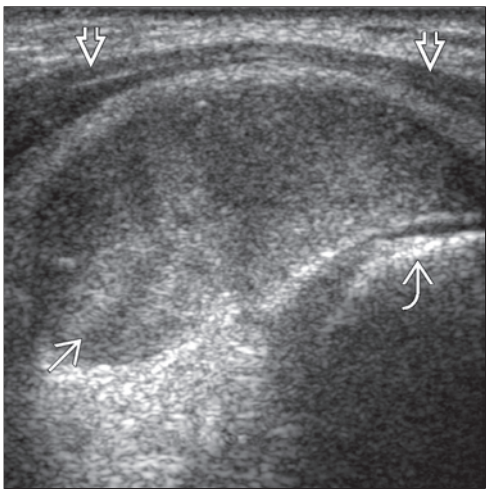


Ganglion Cyst

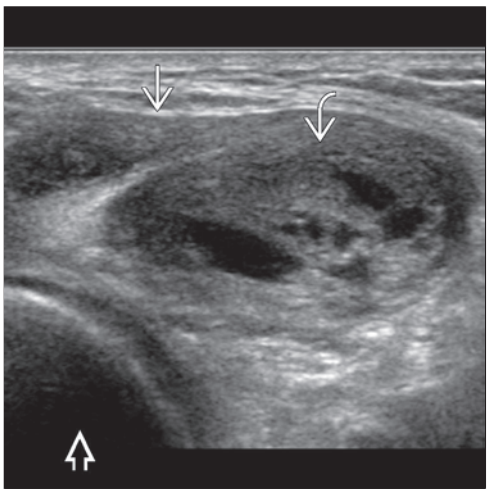


(Left) *Transverse US of the ankle in a patient with acute traumatic swelling shows an acute ganglion cyst* ➪ *containing small echogenic speckles due to colloid aggregates lying alongside the tibia* ➪ *and pointing toward the ankle joint* ➪. *This is an acute traumatic ganglion cyst.* ***(Right)*** *Longitudinal US shows a thick-walled ganglion cyst* ➪ *on the dorsum of the navicular-cuneiform articulation* ➪. *Atypical ganglia occur more commonly in the foot and knee regions.*

Ganglion Cyst

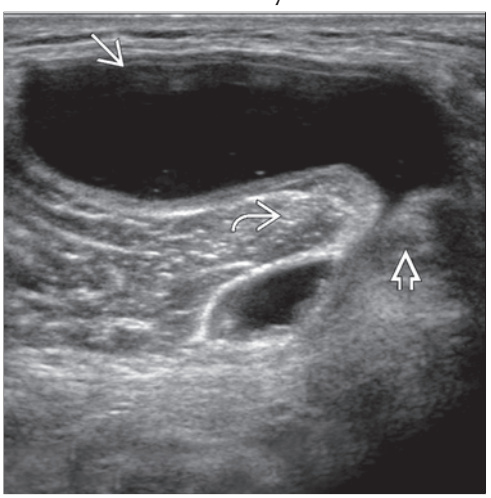


Ganglion Cyst

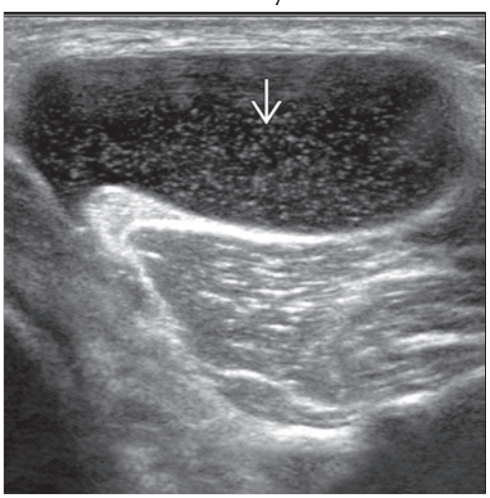


(Left) *Transverse US of the knee region shows a hyperechoic paraarticular ganglion* ➪ *alongside the medial femoral condyle* ➪ *and deep to the sartorius tendon* ➪, *communicating with the joint (not shown). Ganglia may be echogenic due to internal hemorrhage and can simulate a solid tumor.* ***(Right)*** *Transverse US shows a hyperechoic ganglion cyst* ➪ *due to previous intracystic hemorrhage posteromedial to the medial femoral condyle* ➪ *and deep to the sartorius tendon* ➪.

Baker Cyst

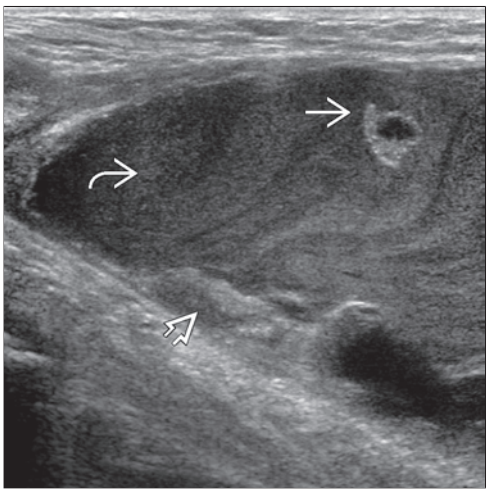


Baker Cyst

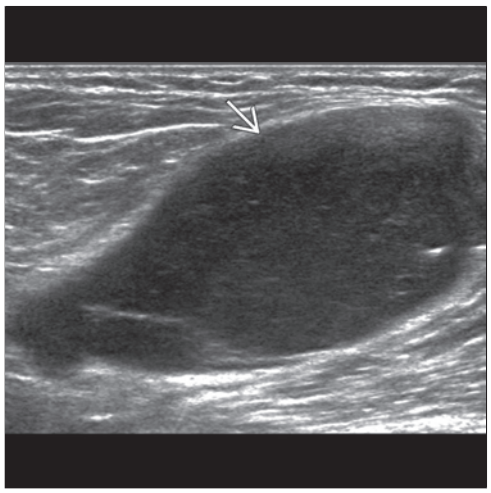


(Left) *Transverse US shows the typical "talk-bubble" configuration of a Baker cyst* ➪. *The beak merges between the medial belly of gastrocnemius* ➪ *and the semimembranous tendon* ➪. ***(Right)*** *Transverse US shows many small echogenic foci* ➪ *within a Baker cyst due to small colloid aggregates. The larger echogenic foci may give rise to "comet tail" artifacts.*

Baker Cyst

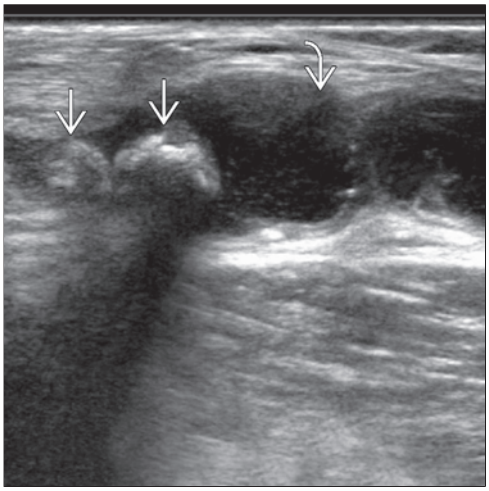


Baker Cyst

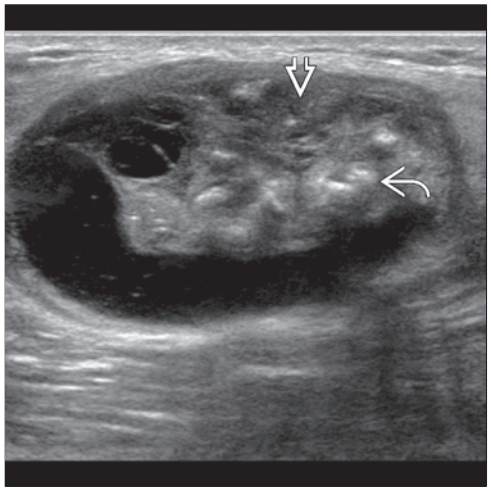


(Left) *Transverse US shows recent hemorrhage within a Baker cyst with fine echogenic fluid. The small hyperechoic ring may be due to a detached synovial fragment.* ***(Right)*** *Longitudinal US shows slightly hyperechoic content of a Baker cyst due to recent intracystic hemorrhage. Aspiration yielded moderately blood-stained fluid. Nearly all Baker cysts will re-fill in a few weeks following cyst aspiration.*

Baker Cyst

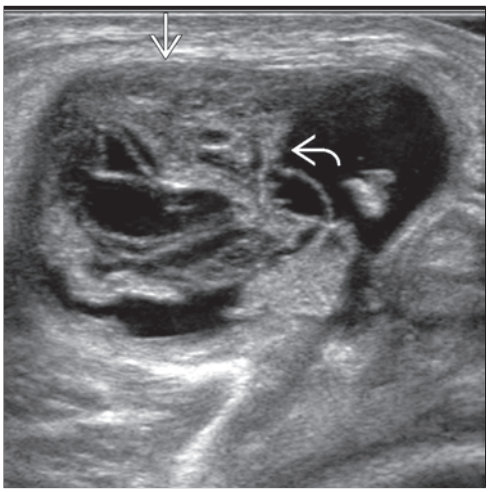


Baker Cyst

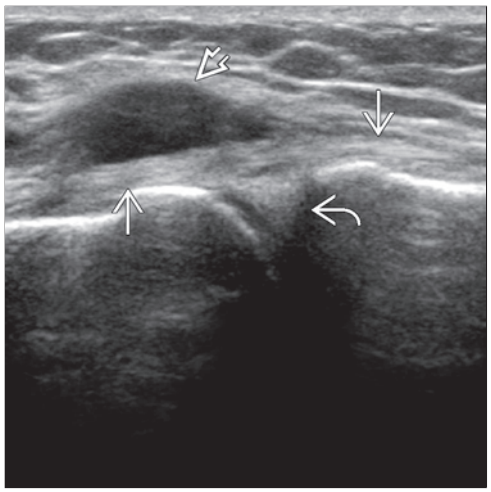


(Left) *Transverse US shows calcified loose bodies within a Baker cyst with posterior acoustic shadowing. Calcified bodies from the knee joint can pass into and continue to enlarge within a Baker cyst being nourished by synovial fluid.* ***(Right)*** *Transverse US shows a Baker cyst containing inflammatory-type synovial proliferation with embedded small calcified foci. This was secondary to an inflammatory knee osteoarthritis with calcified intraarticular debris.*

Baker Cyst



Parameniscal Cyst

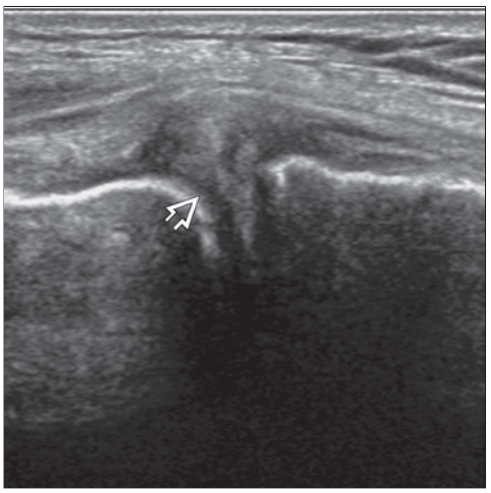


(Left) *Transverse US shows a medium-sized Baker cyst with a large amount of synovial proliferation secondary to an inflammatory-type knee osteoarthritis. The typical "talk-bubble" configuration is still apparent.* ***(Right)*** *Longitudinal US of the knee shows a small parameniscal cyst located superficial to the medial collateral ligament. This extracapsular component of the parameniscal cyst communicated more posteriorly with an intracapsular component alongside the medial meniscus.*

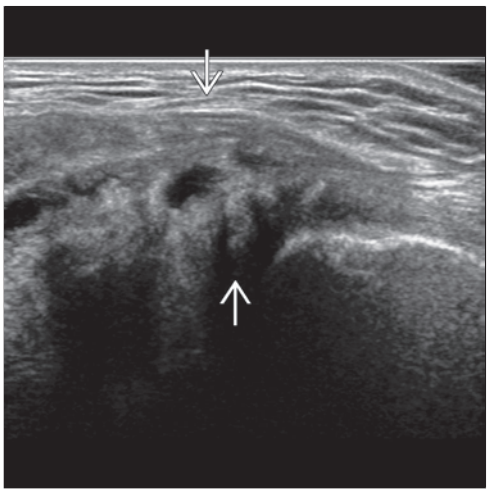
PARAARTICULAR CYSTIC MASS

(Left) *Longitudinal US shows a moderately flattened and extruded medial meniscal body with a peripheral horizontal tear.* ***(Right)*** *Longitudinal oblique US in the same patient at the posteromedial corner of the knee shows a multiloculated paraarticular cystic mass. The distal end of this cyst contacted the edge of the extruded medial meniscus. The soft tissue component is unusual and is due to this parameniscal cyst being associated with hemorrhage around the cyst.*

Parameniscal Cyst

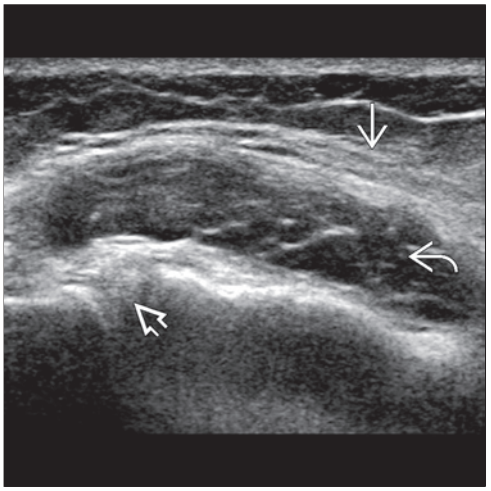


Parameniscal Cyst

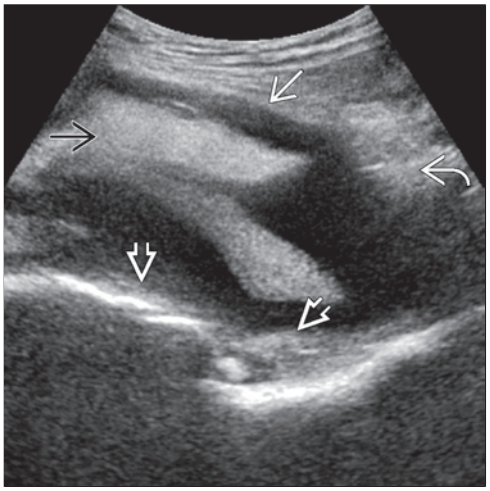


(Left) *Longitudinal US shows a large parameniscal cyst located between the medial collateral ligament and the investing fascia on the medial aspect of knee.* ***(Right)*** *Longitudinal US shows a distended iliopsoas bursa anterior to a nondistended hip capsule. The iliopsoas tendon is displaced anteriorly. The bursa contains thick strands of blood clot and fluid. The aspirate grew Staphylococcus aureus.*

Parameniscal Cyst

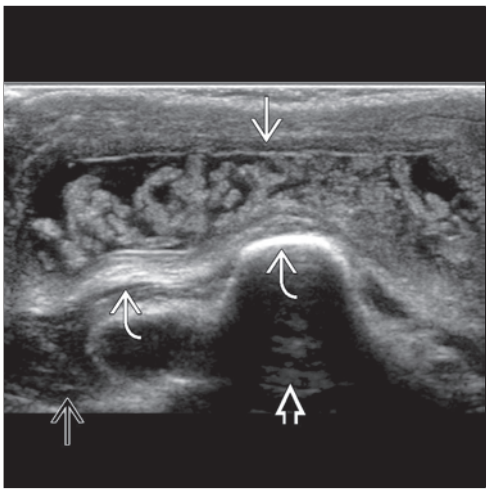


Bursal Distension

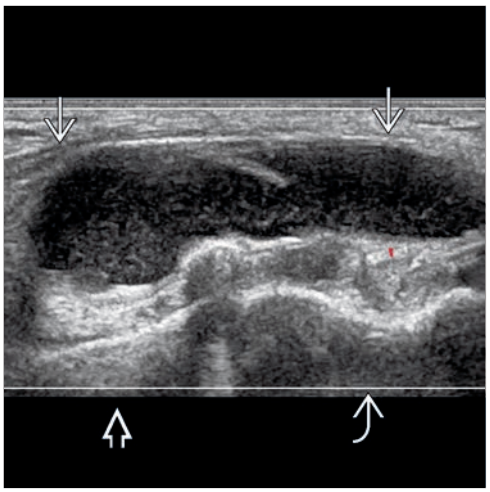


(Left) *Transverse US shows a moderately distended olecranon bursa with frond-like synovial proliferation posterior to the olecranon. The triceps tendon insertion with its radial extension and the anconeus muscle are normal.* ***(Right)*** *Longitudinal color Doppler US shows a subacutely distended adventitial bursa between the iliotibial band and the lateral aspect of the distal femur and tibia. Four mL of blood-stained fluid was aspirated resulting in bursal collapse.*

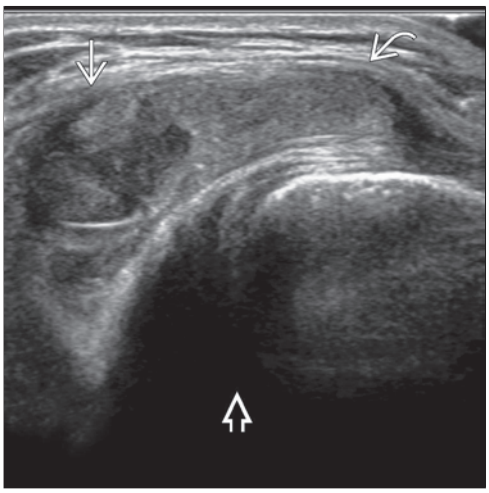
Bursal Distension



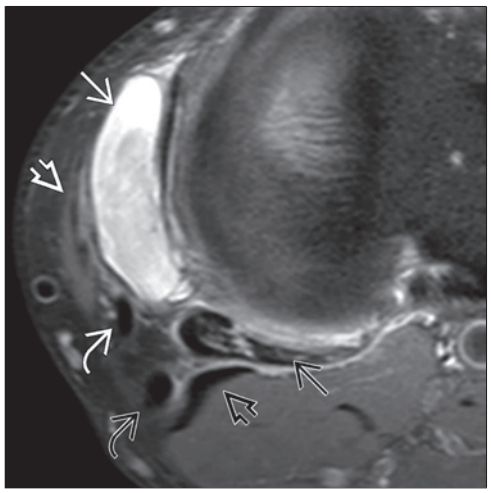
Bursal Distension



Bursal Distension

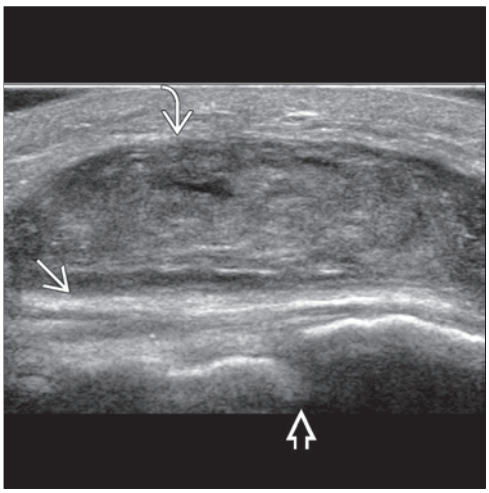


Bursal Distension

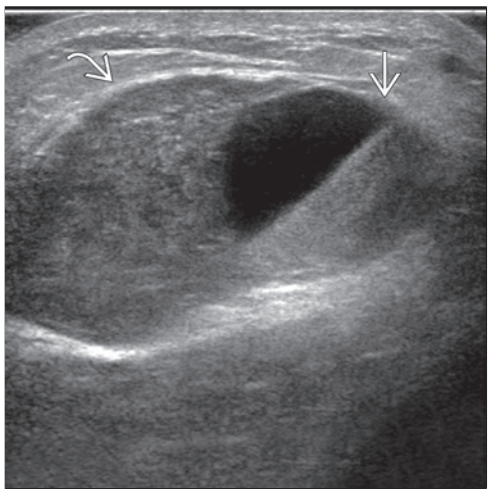


(Left) *Transverse US shows a hemorrhagic pes anserinus bursitis ➔ containing finely echogenic fluid located between the sartorius tendon ➔ and the anteromedial aspect of the proximal tibia ➔.* ***(Right)*** *Transverse PDWI FS MR in the same patient shows the distended hemorrhagic pes anserinus bursa ➔ deep to the sartorius ➔ and gracilis ➔ tendons. The semitendinous ➔, semimembranous ➔, and medial belly of gastrocnemius ➔ tendons are also shown.*

Collection or Hematoma

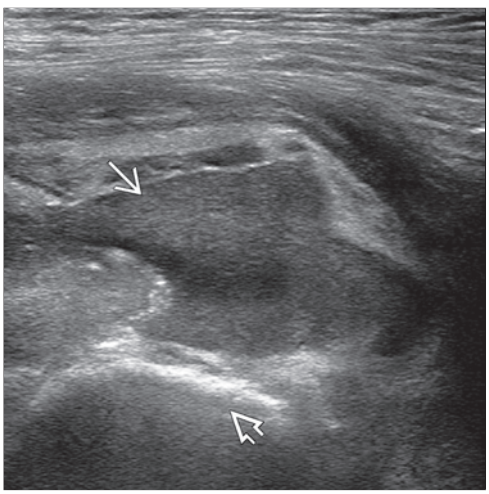


Collection or Hematoma

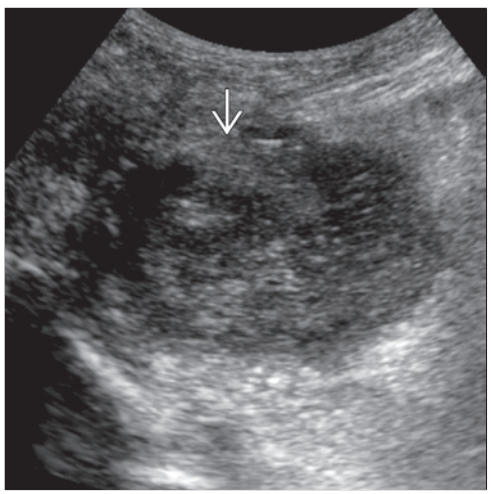


(Left) *Longitudinal US shows a large hematoma ➔ on the medial aspect of the knee joint ➔ superficial to the medial collateral ligament ➔.* ***(Right)*** *Longitudinal US in the same patient at the anteromedial aspect of the knee just anterior to the previous image shows a partially liquefied component of this hematoma ➔ with a fluid level ➔. Aspiration 4 days later confirmed a hematoma.*

Collection or Hematoma



Collection or Hematoma



(Left) *Longitudinal US 1 week following hip arthroplasty ➔ shows a medium-sized collection containing finely echogenic fluid ➔ superior to the hip joint. US-guided aspiration yielded blood-stained fluid with no growth on culture.* ***(Right)*** *Longitudinal US shows a medium-sized hypoechoic fluid collection ➔ anterior to the hip in a patient with recent groin surgery. Aspiration yielded a small amount of blood-stained fluid, which grew Staphylococcus aureus*

SYNOVIAL SWELLING

DIFFERENTIAL DIAGNOSIS

Common
- Osteoarthritis
- Inflammatory Arthropathy
- Tophi of Gout or Pseudogout

Less Common
- Pigmented Villonodular Synovitis (PVNS)
- Focal Nodular Synovitis (FNS)
- Synovial Osteochondromatosis
- Septic Arthritis
- Lipoma Arborescens
- Amyloid
- Synovial Hemangioma
- Synovial Sarcoma
- Synovial Chondrosarcoma

Rare but Important
- Lymphoma

ESSENTIAL INFORMATION

Key Differential Diagnosis Issues
- Diagnosis of synovial mass is based on several features in addition to ultrasound characteristics
  - Clinical features
    - Age of patient, disease onset, and clinical course
  - Pattern of disease
    - Which joint or joints are affected and which part of these joints are affected
  - Radiographic features
    - Joint space narrowing, osteophytes, erosions, mineralization, juxtaarticular osteopenia
  - Ultrasound characteristics
    - Intraarticular or extraarticular mass
    - Degree of synovial thickening
    - Localized or diffuse synovial thickening
    - Degree and character of joint effusion
    - Joint space narrowing, osteophytes, erosions, mineralization
    - Degree of synovial hyperemia
    - Degree of periarticular inflammation
  - Serology: Inflammatory markers, ANF, rheumatoid factor; antibodies to MCV; antibodies to CCP
  - Histology
    - Ultrasound-guided biopsy for histology very useful to differentiate many types of synovial overgrowth
    - Cannot distinguish between synovial inflammation secondary to osteoarthritis, inflammatory arthropathy, or nontuberculous infective arthropathy

Helpful Clues for Common Diagnoses
- **Osteoarthritis**
  - Knees, hips, hands, and feet
  - Increasing age, trauma, excessive physical use, genetics, and obesity are all predisposing factors
  - Variable synovial inflammation is more common in osteoarthritis than previously thought
  - Tends to occur close to areas of pathologically damaged bone and cartilage
  - Only modest correlation between severity of osteoarthritis and degree of synovitis
    - Generally easier to quantify degree of periarticular inflammation on MR than ultrasound
- **Inflammatory Arthropathy**
  - Synovial proliferation with inflammatory arthropathy
    - Diffuse echogenic or hypoechoic synovial proliferation
  - Osteoarthritis changes (marginal osteophytosis, localized joint space narrowing, meniscal degeneration, articular debris) less pronounced
  - Mild to moderate synovial hyperemia typical
- **Tophi of Gout or Pseudogout**
  - Particularly joints of hands, feet, and knee
    - Gout → urate crystal deposition
    - Pseudogout → calcium pyrophosphate dihydrate deposition
  - Tophi are more common in gout
  - Periarticular location
    - Soft or hard tophi
    - ± synovial or intrameniscal deposition
  - Hyperechoic aggregates in synovial fluid
    - "Urate sand" or "snowstorm" appearance
  - Gout: Thin echogenic band on surface of cartilage ("urate icing")
  - Pseudogout: Thin echogenic band in mid zone of articular cartilage

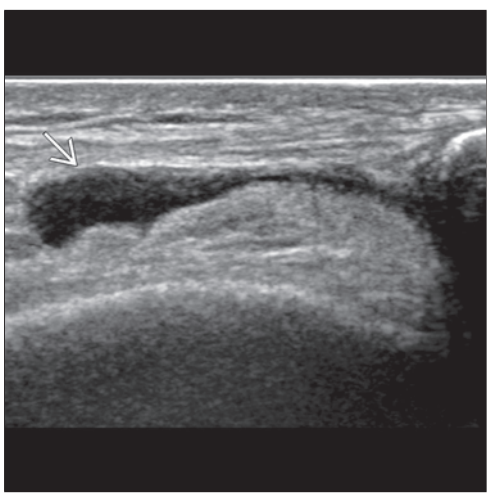
Helpful Clues for Less Common Diagnoses
- **Pigmented Villonodular Synovitis (PVNS)**
  - Benign proliferative synovial disorder
    - Affects synovium of joint, bursa, or tendon sheath
  - Knee > hip > ankle > shoulder
  - Joint involvement is diffuse though may predominate in 1 or several areas of joint
  - Usually moderate to high degree of hyperemia on color Doppler imaging
    - May show little or no hyperemia
  - Characteristic MR pattern on gradient echo imaging due to paramagnetic effect of hemosiderin
    - Foci of synovial hypointensity due to hemosiderin
    - Hemosiderin is present in 85% of PVNS cases (i.e., lack of hemosiderin does not exclude diagnosis)
- **Focal Nodular Synovitis (FNS)**
  - Localized to single area of synovium
    - Although histologically identical, focal disease behaves differently from diffuse disease
    - PVNS and FNS now considered different entities
    - FNS contains less hemosiderin than PVNS
    - FNS does not have frond-like projections
    - FNS becomes more pedunculated rather than more extensive with growth
- **Synovial Osteochondromatosis**
  - Proliferation and metaplastic transformation of synovium
  - Affects any synovium including synovium-lined joint, bursa, or tendon
    - Knee > elbow > hip > shoulder
  - Active synovial proliferation and cartilaginous metaplasia → inactive phase
    - Intrasynovial cartilage nodules detach to lie free in joint and ossify
    - Nodules may consist of cartilage, cartilage/bone mixture, or mature bone with marrow fat
  - Mineralized nodules are hyperechoic; cartilage nodules are hypoechoic
  - Variable-sized joint effusion
  - ± erosion of adjacent cartilage and bone
    - Especially in less distensible joints (hip)
  - ± secondary degenerative change

- **Septic Arthritis**
  - Impossible to distinguish between tuberculous and pyogenic infection based on imaging alone
    - Phemister radiographic triad of severe periarticular osteopenia, marginal erosions, and progressive ↓ in joint space is not specific for tuberculosis
  - With chronic infection, synovial proliferation predominates with little or no synovial fluid
  - Ultrasound-guided synovial biopsy to identify infection and causative organism
- **Lipoma Arborescens**
  - Proliferation of subsynovial fat → villous-like synovial swelling and proliferation
    - Probably secondary to inflammatory or traumatic stimuli
  - Usually presents around 50 years of age
    - Monoarticular with predilection for suprapatellar recess of knee
  - Hyperechoic, frond-like, synovial mass that bends and waves during joint movement on real-time scanning
  - MR appearance is more specific with hypertrophied, subsynovial fatty tissue
- **Amyloid**
  - Amyloid → abnormal accumulation of unrelated insoluble protein with tissues
  - Examples: β_2 microglobulin, immunoglobulin light chains, and serum amyloid A protein
    - Chronic hemodialysis → increased β_2 microglobulin
    - Myeloma → increased monoclonal immunoglobulin light chain fragments
    - Chronic inflammatory condition → ↑ acute-phase protein serum amyloid A
    - May also be idiopathic occurring de novo with no recognizable associated systemic disease
  - Especially affects shoulder, hip, knee, and wrist; usually bilateral
    - Shoulder: Thickening of rotator cuff, bursa, and long head of biceps; periarticular hypoechoic nodules ± bony erosions
- **Synovial Hemangioma**
  - Strictly speaking, most are not hemangiomas
    - Hemangioma = vascular tumor of childhood with proliferative, stable, and involutionary phases
  - Most synovial hemangiomas are synovial vascular malformations
    - Arteriovenous, venous, capillary, lymphatic, or mixed depending on flow and dominant vessel type
  - More common to see vascular malformation involving synovium than vascular malformation confined to synovium
  - Similar to vascular malformations elsewhere; synovial vascular malformations have a predominant vascular or stromal component
    - Stromal component largely composed of many small vessels, too small to resolve on ultrasound
  - ± phleboliths (common)
  - ± ectatic vessels
  - ± venous lakes
  - Usually present first in young adults leading to joint pain, swelling, and repeated hemarthroses
- **Synovial Sarcoma**
  - Named because of similar appearance to synovial tissue under light microscopy
    - However, does not arise from synovium
  - Arises from primitive mesenchymal cells in extraarticular soft tissues
    - < 5% of synovial sarcomas arise from within joint
  - Calcification in up to 50% of synovial sarcomas
    - ± myxoid areas, cystic areas, or hemorrhage
- **Synovial Chondrosarcoma**
  - May occur de novo or in conjunction with synovial chondromatosis
  - Main feature in favor of synovial chondrosarcoma is bony infiltration

Helpful Clues for Rare Diagnoses

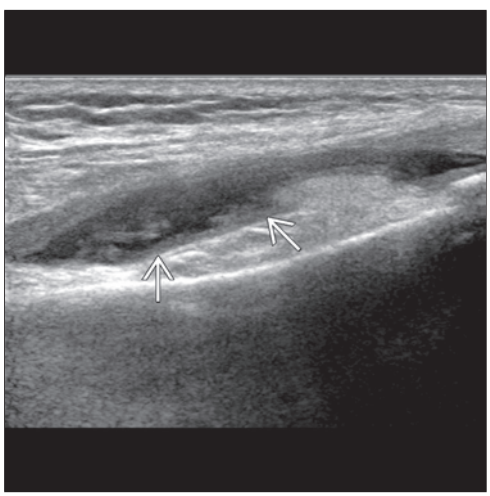
- **Lymphoma**
  - Irregular synovial proliferation
  - Focal irregular cortical osteolysis
  - Regional lymphoma-type adenopathy

Osteoarthritis



Transverse ultrasound shows mild synovial thickening ➔ of the medial patellar recess. This, along with a small joint effusion, is a common finding in osteoarthritis.

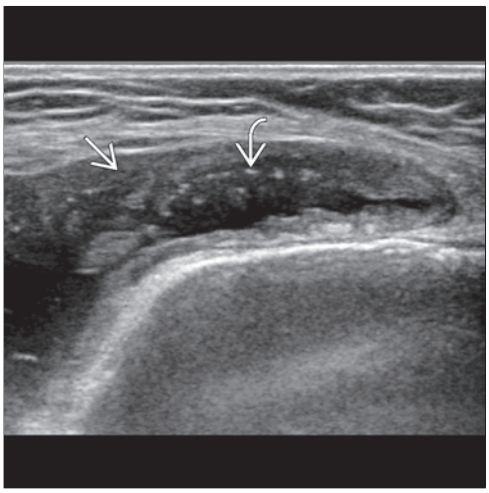
Osteoarthritis



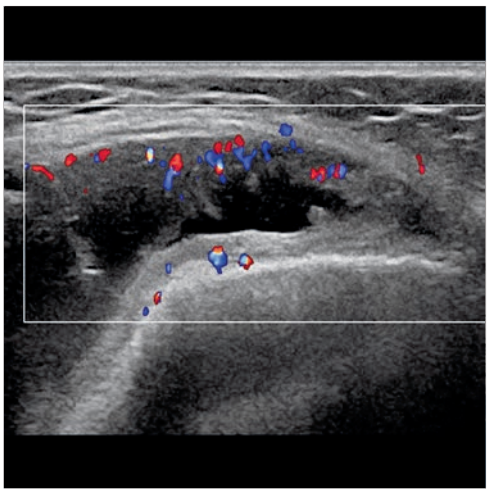
Transverse US shows moderate suprapatellar synovitis ➔ with osteoarthritis. Other signs, besides mild to moderate synovitis, are needed to distinguish inflammatory osteoarthritis from inflammatory arthropathy such as RA.

SYNOVIAL SWELLING

Inflammatory Arthropathy

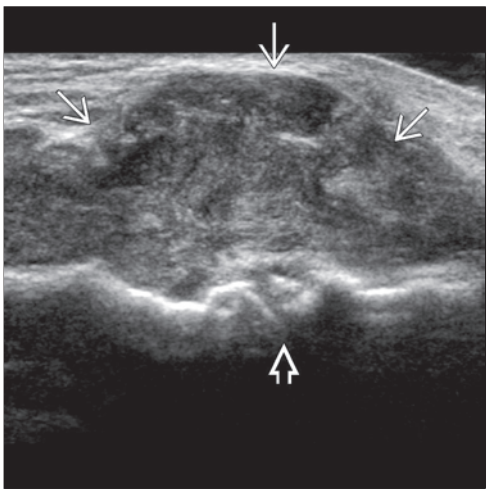


Inflammatory Arthropathy

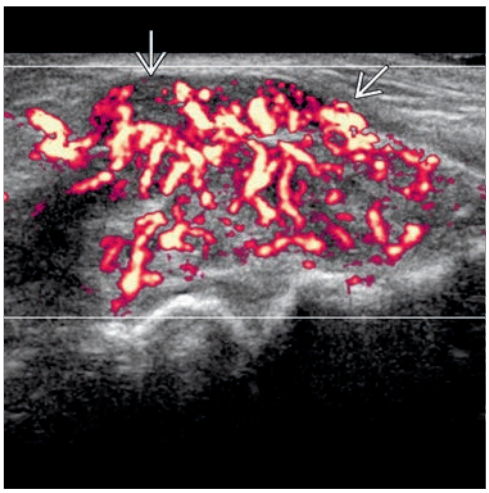


(Left) *Transverse ultrasound shows a small effusion with moderate-severity synovitis of the lateral patellar recess in a patient with RA. There are some small echogenic foci present due to crystal aggregates. This crystal deposition, which can be seen in either OA and RA, is likely to be aggravating the inflammation.* ***(Right)*** *Transverse color Doppler ultrasound shows moderate synovial hyperemia. The degree of hyperemia is a pointer to the level of synovial inflammatory activity.*

Pigmented Villonodular Synovitis (PVNS)

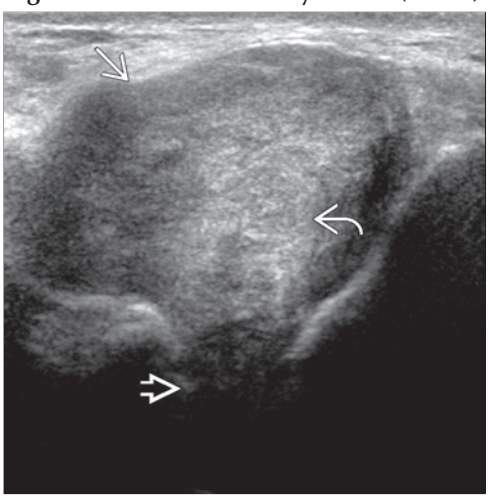


Pigmented Villonodular Synovitis (PVNS)



(Left) *Longitudinal ultrasound of the medial hindfoot shows a large, hypoechoic mass centered on the talocalcaneal articulation. Biopsy confirmed pigmented villonodular synovitis (PVNS).* ***(Right)*** *Longitudinal power Doppler ultrasound of the same patient shows the mass to be highly vascular. This level of hyperemia favors pigmented villonodular synovitis, though not all PVNS tumors are so vascular.*

Pigmented Villonodular Synovitis (PVNS)

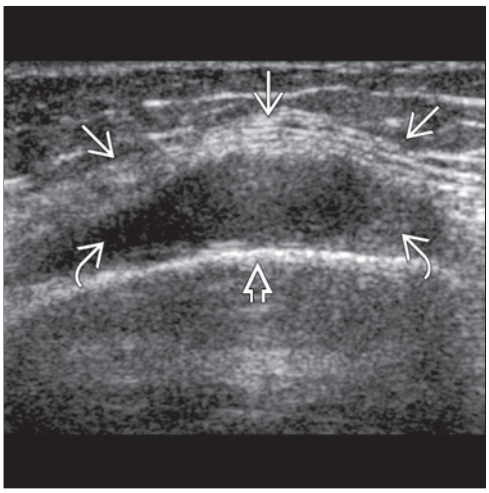


Pigmented Villonodular Synovitis (PVNS)

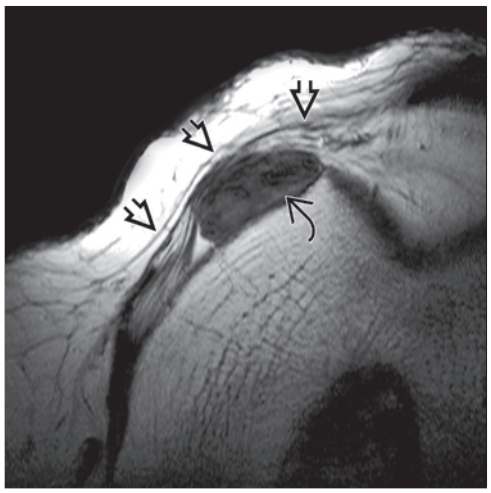


(Left) *Longitudinal ultrasound shows a large mass arising from the lateral aspect of the subtalar joint. This tumor is hyperechoic in parts due to intratumoral hemorrhage. The mass was moderately hyperemic (not shown).* ***(Right)*** *Transverse ultrasound shows markedly thickened hypoechoic synovial thickening of the medial patellar recess of the knee. Ultrasound-guided biopsy revealed PVNS. The hypoechoic nature of the synovium is fairly characteristic of PVNS.*

Focal Nodular Synovitis (FNS)

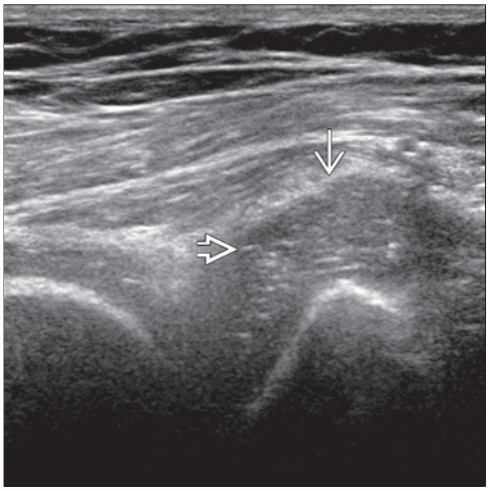


Focal Nodular Synovitis (FNS)

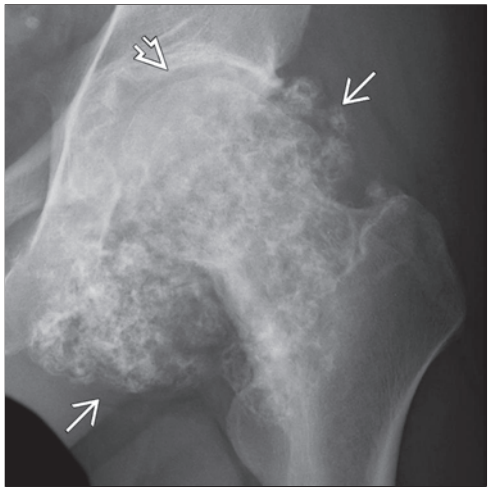


(Left) *Transverse ultrasound of the knee shows a fusiform-shaped, hypoechoic mass between the lateral retinaculum and the femoral cortex. The mass was mildly hyperemic on color Doppler imaging. The appearance suggests focal nodular synovitis.* ***(Right)*** *Axial T2WI MR of the same mass shows a focal, heterogeneous, slightly low signal intensity mass between the lateral retinaculum and the femoral cortex, consistent with nodular synovitis, which was subsequently confirmed histologically.*

Synovial Osteochondromatosis

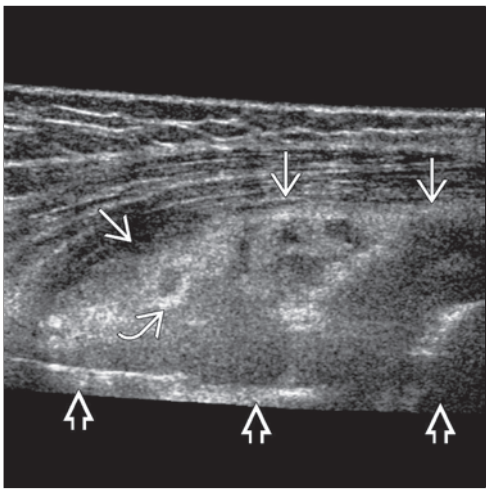


Synovial Osteochondromatosis



(Left) *Longitudinal ultrasound of the knee shows thickened synovial-like tissue containing small echogenic calcific-like foci anteromedially, suspicious of synovial osteochondromatosis. Radiograph revealed no abnormal calcification. Ultrasound-guided biopsy for histology revealed synovial chondromatosis.* ***(Right)*** *Frontal radiograph shows a hip capsule distended with multiple calcific nodules due to synovial osteochondromatosis. Mild to moderate secondary osteoarthritis is present.*

Septic Arthritis



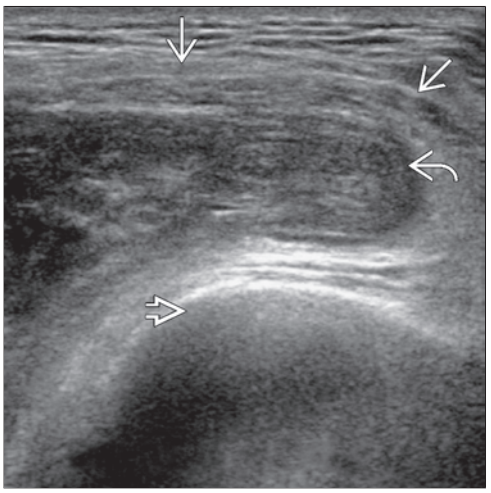
Septic Arthritis



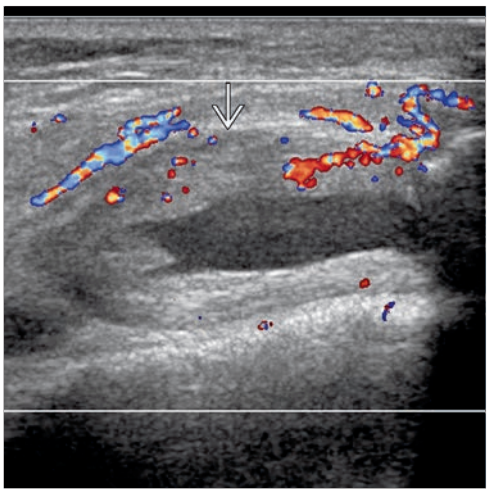
(Left) *Longitudinal ultrasound of the knee shows a large, heterogeneous mass with small cystic areas posterior to the distal femur, initially considered to be a soft tissue tumor. Mild hyperemia was present. Biopsy specimen grew Haemophilus influenzae.* ***(Right)*** *Sagittal T1WI C+ MR in the same patient shows an enhancing mass with synovial enhancement throughout the knee and periarticular inflammation. The inflammatory mass resolved with treatment.*

SYNOVIAL SWELLING

Septic Arthritis

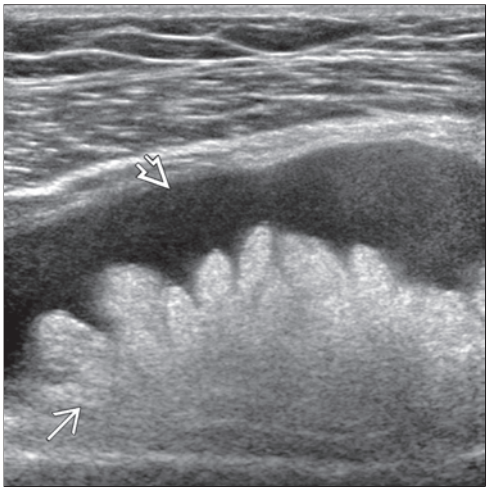


Septic Arthritis

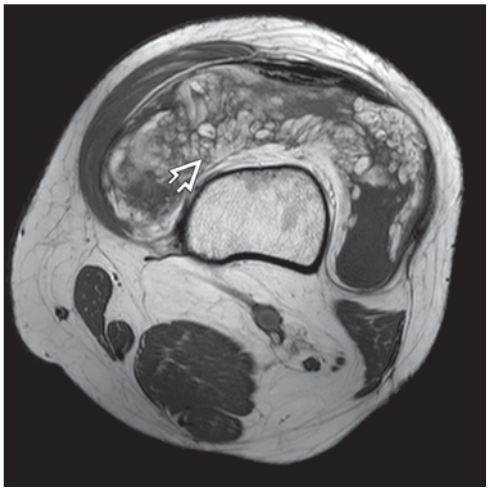


(Left) *Transverse ultrasound shows a severely thickened synovium and capsule of the lateral patellar recess with no effusion. Mild hyperemia was present (not shown). Biopsy revealed tuberculous infection. The femoral condyle is normal.* ***(Right)*** *Transverse color Doppler ultrasound of the knee shows moderate to severe synovial thickening of the medial patellar recess with moderate hyperemia. This patient was known to suffer from disseminated TB, so no synovial biopsy as performed.*

Lipoma Arborescens

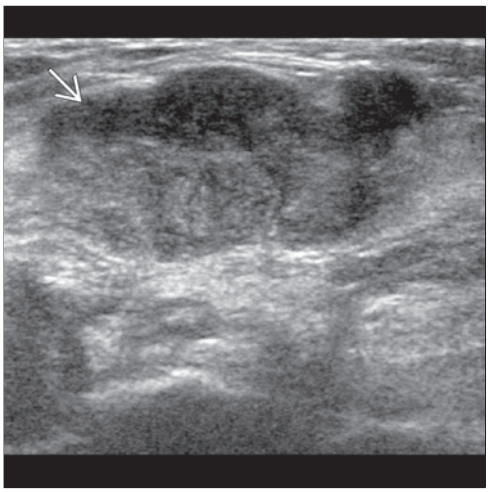


Lipoma Arborescens



(Left) *Longitudinal ultrasound of a patient with chronic knee swelling shows a large effusion with severe frond-like hyperechoic synovial proliferation on the posterior aspect of the suprapatellar pouch. No free nodules are present.* ***(Right)*** *Axial T1WI MR of the same lesion shows frond-like synovial proliferation involving much of the suprapatellar pouch. These fronds have a similar intensity to subcutaneous fat and suppressed on fat-suppressed imaging.*

Amyloid

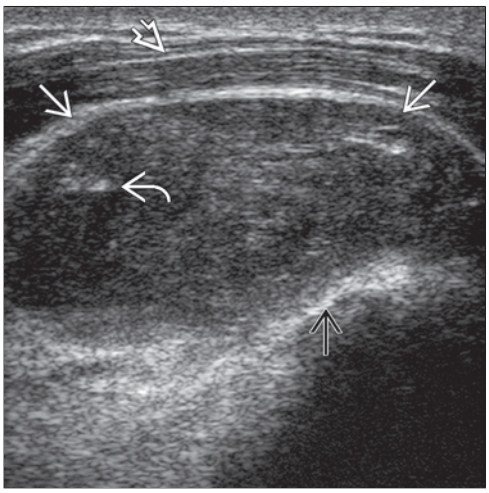


Synovial Hemangioma

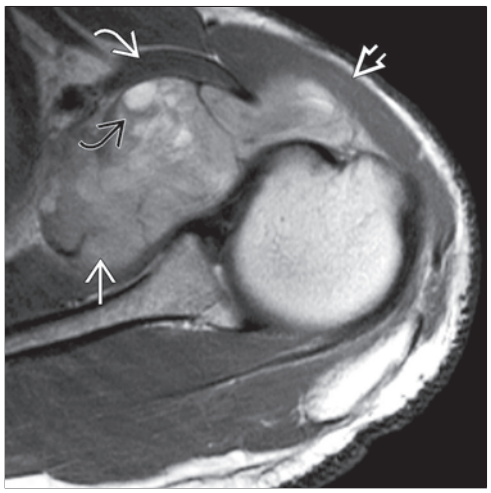


(Left) *Transverse ultrasound shows a well-defined, hypoechoic, lobulated, peritendinous mass on the medial side of the ankle in a patient on hemodialysis. Biopsy specimen revealed amyloid.* ***(Right)*** *Axial T2WI MR with fat suppression shows a venous vascular malformation of the knee, particularly involving the medial retinaculum and extending to the prepatellar region. There is a small joint effusion. This is consistent with synovial hemangioma.*

Synovial Sarcoma



Synovial Sarcoma

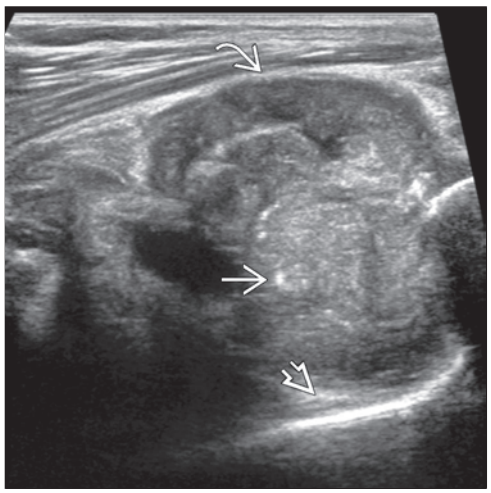


(Left) *Transverse ultrasound of the shoulder shows a large, hypoechoic mass with small echogenic areas, which may represent hemorrhage, deep to the deltoid muscle. Note the humerus. **(Right)** Axial T2WI MR of the shoulder in the same patient shows a mildly hyperintense mass with small cyst-like areas, deep to the pectoralis and deltoid muscles. Biopsy specimen confirmed synovial sarcoma.*

Synovial Chondrosarcoma

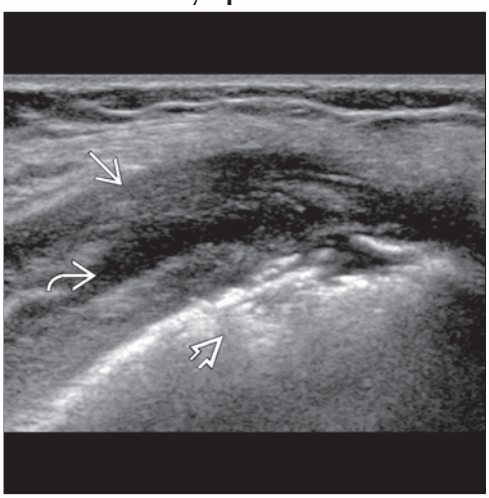


Synovial Chondrosarcoma

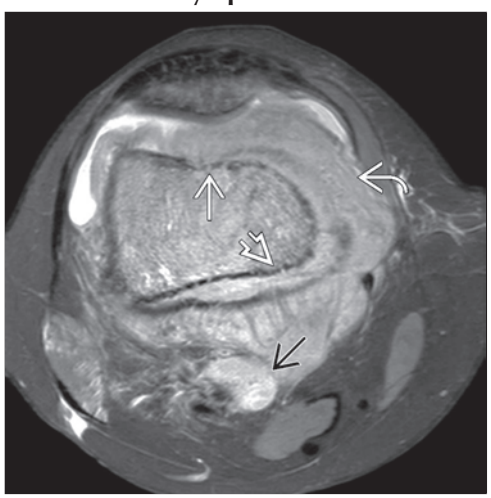


(Left) *Lateral radiograph of the knee in a patient with knee swelling for 20 years shows severe erosion of the posterior aspect of the lateral femoral condyle and supracondylar area. **(Right)** Longitudinal ultrasound of the same knee shows a large, lobulated mass on the posterior aspect of the knee joint with posterior bone scalloping. Some small calcific-type foci are present. Histology following ultrasound-guided biopsy revealed synovial chondrosarcoma.*

Lymphoma



Lymphoma



(Left) *Transverse ultrasound shows severe synovial thickening with a small knee joint effusion and cortical resorption of the medial femoral condyle. TB infection was initially suspected. **(Right)** Axial T2WI FS MR of the same patient shows the mass extending from the medullary canal of the distal femur with cortical resorption, periosteal thickening, and synovial thickening. There is an enlarged popliteal lymph node. Synovial biopsy revealed B-cell lymphoma.*

JOINT EFFUSION

DIFFERENTIAL DIAGNOSIS

Common
- Osteoarthritis

Less Common
- Inflammatory Arthropathy
- Crystal Arthropathy
- Infective Arthritis
- Hemarthrosis
- Lipohemarthrosis
- Pigmented Villonodular Synovitis
- Synovial (Osteo)Chondromatosis

ESSENTIAL INFORMATION

Key Differential Diagnosis Issues
- Characterization of underlying arthropathy relies on disease pattern rather than single ultrasound characteristic
  - Speed of onset, joints affected, severity of disease, age of patient, associated features, and radiographic and ultrasound appearances
  - Oligoarticular or polyarticular location is a feature of both inflammatory or degenerative arthropathy
- Ultrasound is helpful in assessing disease activity and characterization
- Amount and echogenicity of fluid are useful to note but lack specificity
  - Amount and appearance of joint fluid in osteoarthritis, inflammatory arthropathy, repeated hemarthrosis, and septic arthritis may appear very similar
    - Distinguish among these entities by noting concurrent ultrasound features, history, and clinical presentation
    - Check especially for crystal aggregates, which are indicative of crystal arthropathy
    - Crystal arthropathy can coexist with osteoarthritis, infective arthritis, and other causes of joint effusion
- If joint fluid is hyperechoic, keep joint still for several minutes
  - Facilitates sedimentation of contents, which may help diagnosis
    - If 2-layered, more likely hemorrhagic; infective fluid does not sediment readily
    - If 3-layered, diagnostic of lipohemarthrosis
  - Ultrasound-guided fluid aspiration is often necessary and very helpful
    - Specimen for crystals needs to be sent fresh, since saline or alcohol will dissolve crystals

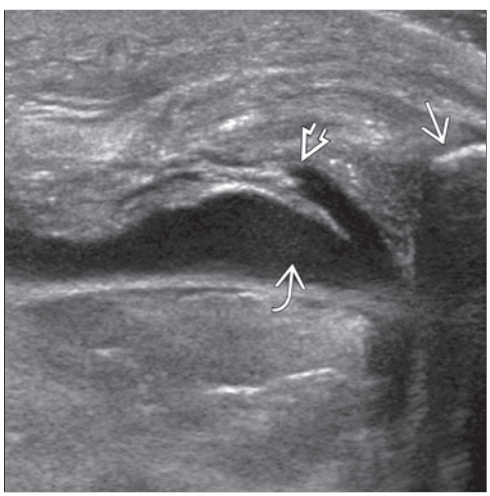
Helpful Clues for Common Diagnoses
- **Osteoarthritis**
  - Most commonly affects knee, hip, interphalangeal, 1st carpometacarpal, triscaphe, wrist, acromioclavicular, and tarsal joints
  - Joint space narrowing, marginal osteophytosis, capsular swelling, synovitis, and effusion are ultrasound signs of osteoarthritis (OA)
  - Variable increase in joint fluid
  - Variable degree of reactive-type inflammatory synovial proliferation
  - ± variable periarticular inflammation
    - Inflammatory component is important to note because this determines response to anti-inflammatory medication
  - Ultrasound is increasingly used to determine inflammatory component of OA and differentiate OA from crystal deposition disease or inflammatory arthropathy
  - Inflammatory element of OA is characterized by
    - Capsular thickening, joint effusion, synovial proliferation, synovial and pericapsular hyperemia, edema of periarticular soft tissues

Helpful Clues for Less Common Diagnoses
- **Inflammatory Arthropathy**
  - Affects any synovial-lined joint
    - Often bilateral and symmetrical
  - Ranges from single (monoarthropathy) to few (oligoarthropathy) to multiple (polyarthropathy) joint involvement
  - Most common finding: Pannus
    - Diffusely thickened hyperechoic or hypoechoic synovium
    - Frond-like or nodular synovial proliferation
    - May resemble echogenic or hypoechoic synovial fluid
  - Effusion may be anechoic or hyperechoic
  - ± echogenic speckles due to precipitated fibrin or inflammatory debris
  - ± marginal erosions
    - Well-defined, small, periarticular defects
    - Coalesce to form larger erosions and more generalized marginal irregularity of joint
    - Ultrasound is more sensitive than radiography and MR at detecting small joint periarticular erosions
    - Ultrasound is less sensitive than contrast-enhanced MR
  - Color Doppler imaging
    - Helpful for estimating level of disease activity and distinguishing synovium from joint fluid
    - Hyperemia is more easily appreciated in smaller joints (e.g., hand, wrist, elbow) than larger joints (e.g., shoulder, hip)
    - Active pannus leads to increased color flow
    - Hyperemia is graded semiquantitatively as high, intermediate, or low/absent vascularity
    - Quantitative analysis of hyperemia is feasible, though semiquantitative analysis is adequate for clinical use
  - Other signs include joint space narrowing, subluxation, deformity, and ankylosis
  - Coexistent soft tissue features include tenosynovitis, bursitis, and entrapment neuropathy
- **Crystal Arthropathy**
  - Always consider in any acute arthritis
  - Effusion can be anechoic or hyperechoic
  - Gout results from urate crystal deposition
    - 1st metatarsophalangeal joint is 1st affected joint in 50%; later becomes polyarticular
    - Best diagnostic clue: Identification of echogenic foci with "comet tail" artifacts within and around joint
    - ± "urate sand" (fine punctuate echoes) or "sandstorm" (larger echogenic aggregates) appearance
    - ± urate deposition on articular cartilage surface as thin echogenic band ("urate icing")

- Soft tophi (no acoustic shadowing) → hard tophi (dense acoustic shadowing)
- Pseudogout associated with calcium pyrophosphate dihydrate deposition
  - Knee, wrist, scaphotrapezium articulation
  - More often associated with osteoarthritis
  - Crystal deposition in mid zone of articular cartilage → more prolific cartilage loss
  - ± chondrocalcinosis of fibrocartilage (menisci, articular disc of triangular fibrocartilaginous complex, glenoid or acetabular labrum)
  - Tophi are less common in pseudogout

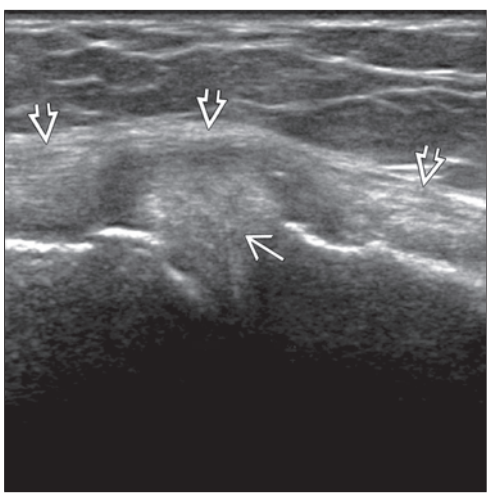
- **Infective Arthritis**
  - Gradual-onset joint swelling over 1-2 days
  - Very tender with marked limitation of movement
  - Usually hematogenous spread
    - ↑ in immunosuppressed patients, diabetics, and patients with rheumatoid arthritis
  - Joint effusion
    - Cardinal sign of septic arthritis
    - Swirling or moving echoes on real-time imaging
    - Anechoic joint fluid does not exclude septic arthritis
  - For most joints, no effusion equates to no septic arthritis
  - 2 exceptions to rule
    - For nondistensible diarthrodial joints, such as acromioclavicular joint, effusion is minimal
    - If joint capsule is not intact following rupture or recent surgery, no effusion will develop
  - Echogenic fluid due to aggregates of inflammatory debris
  - Findings in more chronic infections
    - Synovial proliferation and capsular thickening
    - Viscosity of joint fluid increases
    - Amount of joint fluid decreases
    - Progressive joint space narrowing (chondrolysis)
    - Marginal erosions (osteolysis)
    - Periarticular soft tissue extension
  - Ultrasound-guided fluid aspiration for Gram stain, culture, and cytology is helpful
  - Ultimate diagnosis rests on isolating pathogens from aspirated joint fluid
- **Hemarthrosis**
  - History of trauma or known coagulopathy
    - ± associated fracture
  - Initially finely speckled echogenic joint fluid
  - After ~ 5 minutes, shows more or less 2-layered appearance of joint effusion
  - Subacute stage
    - Blood clots → discrete echogenic foci within joint
    - Joint fluid is largely anechoic
    - ± fibrinous adhesions
  - Repeated hemarthroses
    - Variable synovial thickening
    - Common and severe in patients with hemophilia with repeated hemorrhage
    - ± bone overgrowth and secondary osteoarthritis-type picture
    - ± progressive joint disorganization
    - ± pseudotumor (expanding hematoma)
- **Lipohemarthrosis**
  - Leakage of marrow fat into joint cavity
    - Presence of lipohemarthrosis implies fracture communicating with joint
  - Initially finely speckled echogenic joint fluid
  - After ~ 10 minutes, shows 3-layered appearance of joint effusion
  - 3 layers that become evident are
    - Fat layer: Least dependent layer (fat)
    - Serum layer: Middle layer (supernatant serum)
    - Cellular layer: Most dependent layer (red blood cell [RBC] aggregates)
  - ± hypoechoic areas within floating fat due to trapped blood
- **Pigmented Villonodular Synovitis**
  - Diffusely thickened hypoechoic synovium
  - Variable hyperemia
  - ± hemorrhagic joint effusion
- **Synovial (Osteo)Chondromatosis**
  - Diffuse synovial proliferation ± small echogenic foci (ossification)
  - Variably echogenic nodules within effusion

Osteoarthritis



Transverse ultrasound of the knee shows a mildly distended medial patellar recess ⇒ with moderate synovial proliferation extending into a synovial plica ⇒. The patella ⇒ is normal.

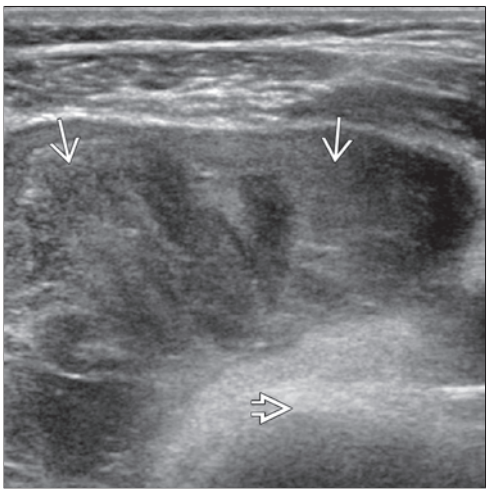
Osteoarthritis



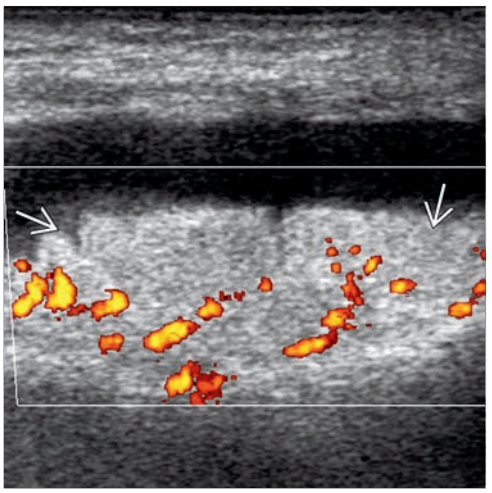
Longitudinal ultrasound shows moderate extrusion of medial meniscal body ⇒, indicative of meniscal degeneration with joint space narrowing due to osteoarthritis. Medial collateral ligament ⇒ is displaced.

JOINT EFFUSION

Inflammatory Arthropathy

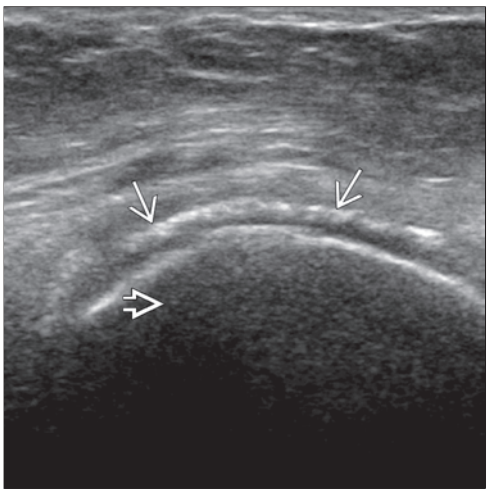


Inflammatory Arthropathy

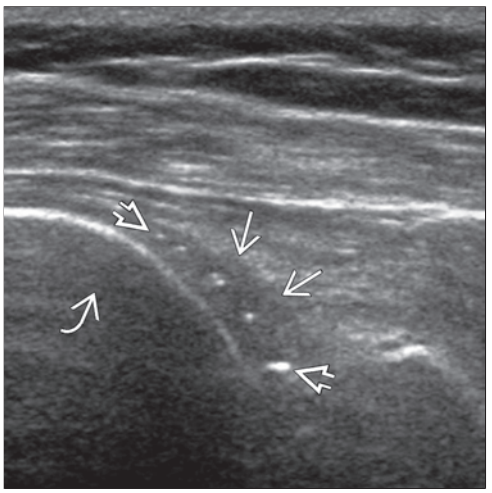


(Left) *Transverse ultrasound shows both marked echogenic and hypoechoic synovial proliferation distending the medial knee recess in a patient with rheumatoid arthritis. This is not specific for inflammatory arthropathy and may be seen with infection or repeated hemarthrosis. Minimal, if any, synovial fluid is present. Note the distal femur.* ***(Right)*** *Longitudinal ultrasound shows severe synovial proliferation with moderate hyperemia in the suprapatellar pouch of the knee.*

Crystal Arthropathy

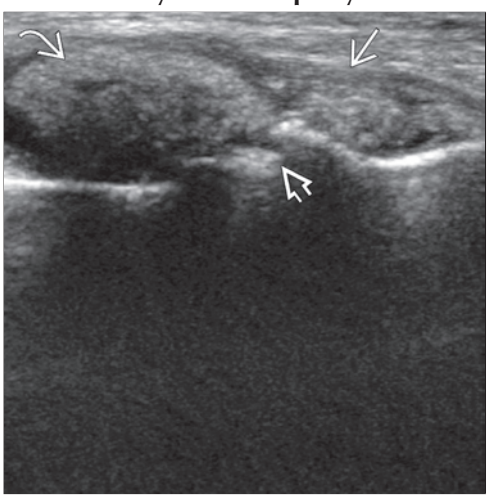


Crystal Arthropathy

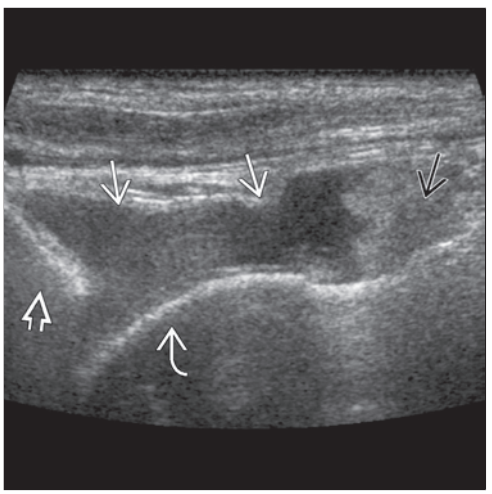


(Left) *Longitudinal ultrasound shows an echogenic midzonal band of articular cartilage calcification of the femoral condyle posteriorly, indicative of calcium pyrophosphate deposition. Other images (not shown) showed meniscal chondrocalcinosis.* ***(Right)*** *Transverse ultrasound shows gouty arthritis of the glenohumeral joint. There is a small joint effusion with small echogenic crystal deposits on the humeral articular cartilage surface ("urate icing").*

Crystal Arthropathy

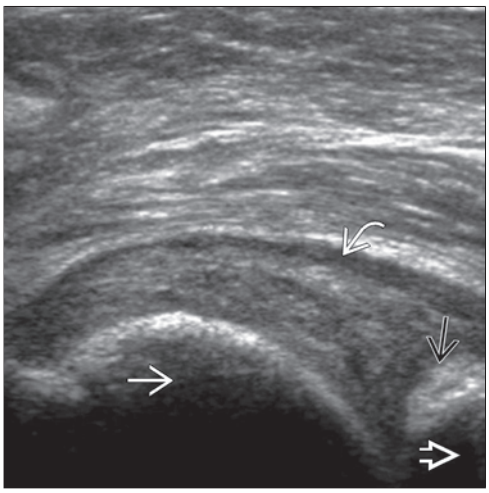


Infective Arthritis

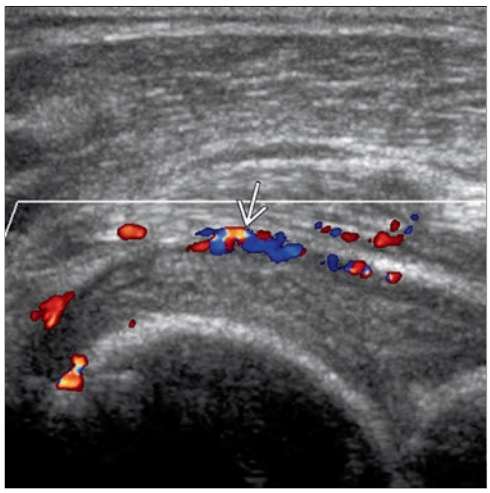


(Left) *Longitudinal ultrasound shows an echogenic effusion ("urate sand") of the 1st metatarsophalangeal joint in a patient with chronic gout. There is also a more well-defined intracapsular soft tophus.* ***(Right)*** *Longitudinal ultrasound shows partially hypoechoic, partially hyperechoic fluid distending the ankle joint and displacing intracapsular extrasynovial fat. Aspiration yielded pus, which grew Staphylococcus aureus. The talar dome and distal tibia are normal.*

Infective Arthritis

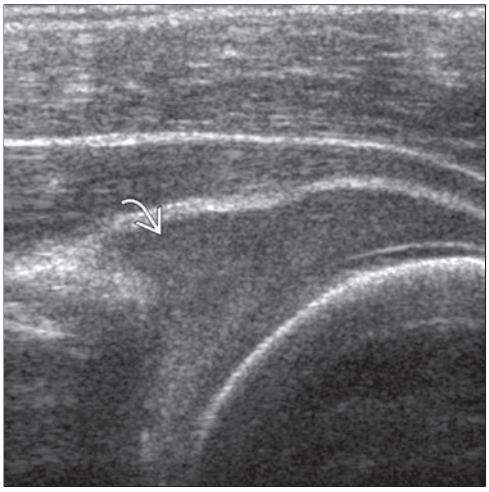


Infective Arthritis

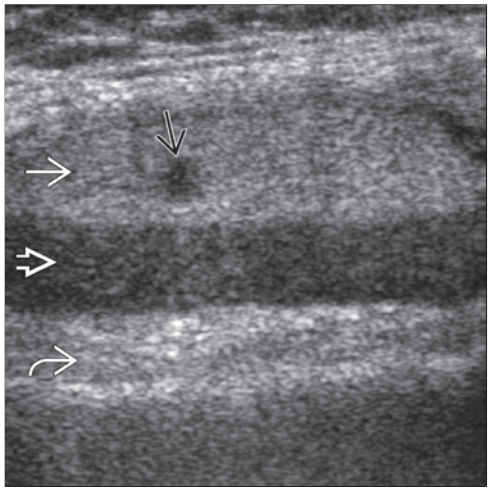


(Left) *Transverse ultrasound shows the posterior aspect of the glenohumeral joint, which is distended by synovial proliferation due to chronic septic arthritis. The humeral head, glenoid, and posterior labrum are normal.* ***(Right)*** *Transverse color Doppler ultrasound of the same patient shows moderate peripheral hyperemia of the thickened synovium. Clinical findings, serology, and synovial biopsy will help exclude an inflammatory arthropathy.*

Hemarthrosis

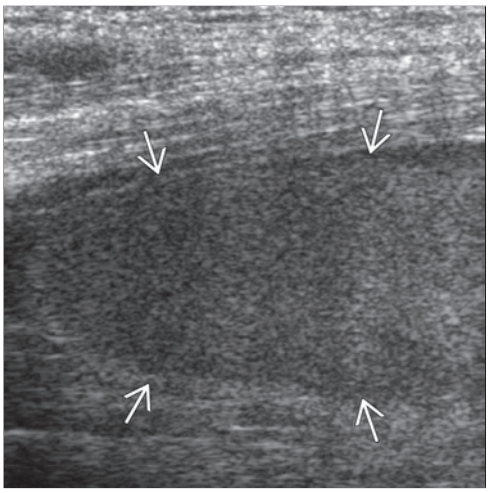


Lipohemarthrosis

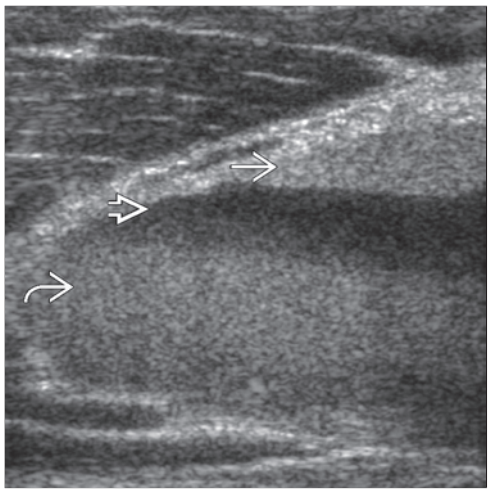


(Left) *Transverse ultrasound shows echogenic fluid distending the glenohumeral articulation due to acute hemarthrosis. This is usually secondary to a large rotator cuff tear.* ***(Right)*** *Transverse ultrasound of the suprapatellar pouch shows a lipohemarthrosis with fat, serum, and cellular layers. The hypoechoic area in the fat layer is due to the entrapped blood. This patient had a fracture of the tibial plateau (not shown).*

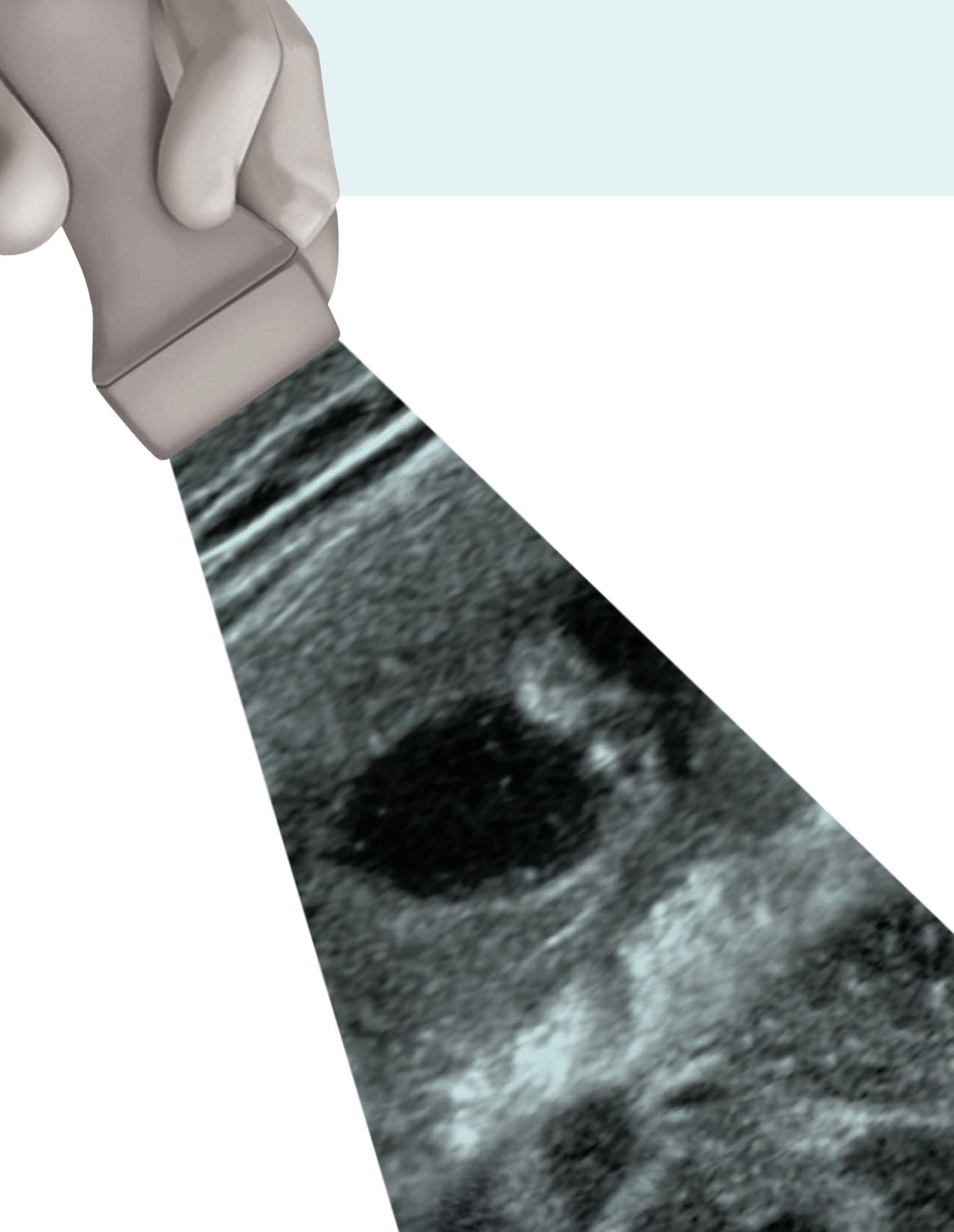
Lipohemarthrosis



Lipohemarthrosis



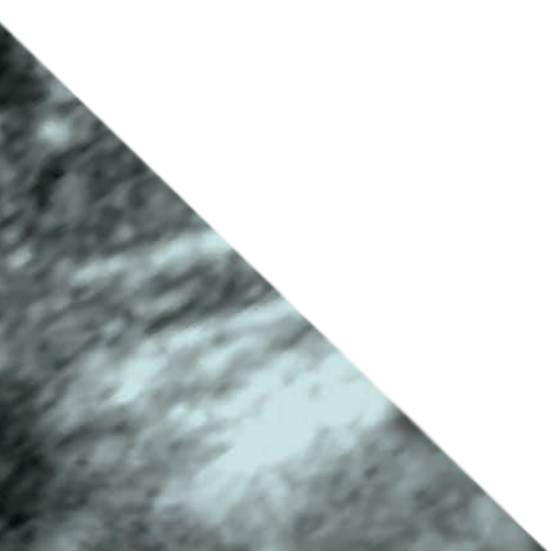
(Left) *Longitudinal ultrasound of the knee in a patient with a tibial plateau fracture shows marked distension of the suprapatellar pouch with echogenic fluid.* ***(Right)*** *Longitudinal ultrasound at the same location, after keeping the joint still for 15 minutes, shows separation of the fluid contents into fatty, serous, and cellular components. Lipohemarthrosis implies communication between joint and marrow cavity and is nearly always due to a bone fracture.*



SECTION 5

Chest and Abdominal Wall

Chest Wall Lesion **III**-5-2
Abdominal Wall Mass **III**-5-8



CHEST WALL LESION

DIFFERENTIAL DIAGNOSIS

Common
- Acute Rib Fracture
- Healing Rib Fracture
- Rib Metastases

Less Common
- Muscle Metastases
- Hematoma
- Lipoma
- Elastofibroma Dorsi
- Fibroma
- Carcinoma, Male Breast
- Gynecomastia
- Accessory Breast
- Prominent Xiphoid Process
- Prominent Rib
- Costochondritis
- Accessory Muscle
- Lymphatic Malformation
- Vascular Malformation
- Abscess
- Sternoclavicular Joint Arthropathy

ESSENTIAL INFORMATION

Key Differential Diagnosis Issues
- Ultrasound is very useful for chest wall lesions as structures are superficial and readily visible on high-resolution ultrasound
  - Retroscapular region is only area not accessible
- For rib fractures, examine around painful area only
- Ask patient to place finger over most painful area
  - Caveat: US is less helpful in unconscious, uncooperative patients and young children
- No need to examine all ribs

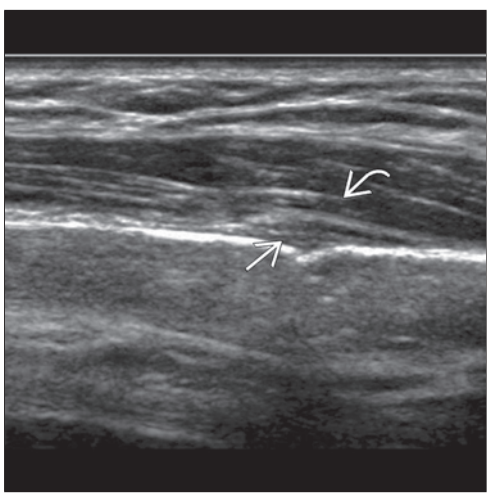
Helpful Clues for Common Diagnoses
- **Acute Rib Fracture**
  - History of trauma
  - Localized tenderness
  - Sharp break in superficial bone cortex
    - ± displacement or angulation
    - ± adjacent soft tissue swelling or hypoechoic hematoma
    - Wide break in cortex or cortical irregularity suggests pathological fracture
  - Rib fractures usually occur in vertical line
    - Check adjacent ribs along rib fracture
  - Ultrasound will detect 10x more rib fractures than radiography
    - Also able to accurately detect fractures of costal cartilage or costochondral junction
  - Ultrasound is more accurate than radiography at detecting pneumothorax
    - Loss of normal "to and fro" respiratory motion at pleural surface on real-time scanning over least dependent portion of hemithorax
    - No movement at echogenic pleural surface
- **Healing Rib Fracture**
  - Fracture margin is less sharp and more rounded
  - Progressive bridging callus
    - Initially hypoechoic mass alongside fracture
    - Progressive ossification of callus with ↑ echogenicity and ↑ acoustic shadowing
    - After approximately 2 months, only cortical bump without visible fracture line will remain
    - Cortical contour will take from months to years to remodel to normal
  - Ultrasound can accurately discriminate between acute and non-acute rib fracture
- **Rib Metastases**
  - Common site of osseous metastases
  - Lung, kidney, hepatocellular carcinoma, and bowel are all common primary sites
  - Usually multiple
    - Randomly located, as opposed to linear vertical location of rib fractures
  - Can be detected only if cortex is disrupted
    - Metastases usually originate in medullary canal prior to infiltrating cortices
    - Therefore, US has low sensitivity for detecting rib metastases
  - If cortex disrupted, US accurate at distinguishing metastatic from traumatic fracture
  - Bone destruction
    - Irregular thinning or loss of echogenic superficial cortex of rib
    - ± soft tissue mass at site of bony destruction

Helpful Clues for Less Common Diagnoses
- **Muscle Metastases**
  - Feature of advanced malignancy
  - Relatively uncommon, possibly due to
    - Destruction of tumor cells due to muscle motion
    - Muscle pH inhospitable to tumor cells
    - Muscle prevents build up of tumor-produced lactic acid that induces tumor neovascularity in other tissues
  - Varied primary tumors (melanoma, pancreatic, kidney, colon, lung, stomach, ovary, hepatocellular carcinoma, etc.) → muscle metastases
  - Soft tissue mass
    - ± hyperemia
    - ± surrounding edema
    - ± central necrosis (uncommon)
- **Hematoma**
  - Due to trauma, anticoagulation, strenuous and prolonged coughing, vascular malformation
  - Often within pectoralis or intercostal muscles
  - Mildly echogenic mass
    - ± concentric layering liquefaction
    - ± marginal hyperemia
- **Lipoma**
  - Similar appearances to lipoma elsewhere
  - Hypoechoic, well-defined, soft tissue mass with fine echogenic striations
- **Elastofibroma Dorsi**
  - Uncommon; benign, slow-growing, connective tissue tumor
    - Subscapular area (99%), more common in elderly and in females (60%), frequently bilateral
    - More common in persons who perform manual labor
    - Tumor composed of abnormal elastic fibers
    - Generally regarded as fibroblastic reactive process or pseudotumor
  - Large, well-circumscribed tumor
  - Alternating bands of hypoechoic (fat) and hyperechoic (fibrous) tissue

- Usually only minimal hyperemia on color Doppler imaging
  - Can occasionally be difficult to distinguish from surrounding muscle

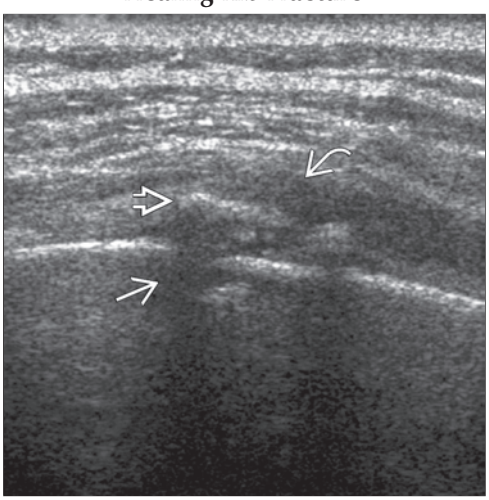
- **Fibroma**
  - Hypoechoic subcutaneous nodule
  - Well-defined or ill-defined border
- **Carcinoma, Male Breast**
  - Multilobulated cystic pattern more common than mixed cystic-solid pattern
  - Ill-defined margin more common than well-defined margin
  - Mildly hypervascular, mainly peripheral
- **Gynecomastia**
  - Growth of glandular tissue in male breast
  - Pseudogynecomastia = ↑ fat in male breast
  - Most cases are idiopathic
  - Identifiable causes include
    - Congenital anorchia, Klinefelter syndrome
    - Hermaphroditism, adrenal carcinoma
    - Liver disorders, drugs (spirolactone, cimetidine, estrogen derivatives)
  - Glandular hyperplasia occurs in retroareolar region and is hypoechoic
    - Branches out in triangular fashion beyond retroareolar region
    - Progressive glandular proliferation → more diffuse echogenic fibrotic proliferation
- **Accessory Breast**
  - Extra breasts may appear ± nipples or areolae
  - Presence of breast tissue outside normal breast contour
  - Mass anywhere along the course of embryologic mammary streak (axilla to inguinal region)
- **Prominent Xiphoid Process**
  - Cartilaginous lower end of sternum, which normally points slightly forward
  - If large, or if pectus excavatum, may be felt as palpable mass
- **Prominent Rib**
  - Rib lies more superficial than the rest
- **Costochondritis**
  - Swelling of chondral part of rib ± adjacent inflammatory change
    - Ultrasound may be normal despite characteristic symptoms
- **Accessory Muscle**
  - Pectoralis major muscle: Many variants
    - Aplasia (Poland syndrome), hypoplasia, pectoralis minimus, pectoralis quartus, pectoralis intermedius, pectoralis anomalous
  - Sternalis: Strap-like accessory muscle along sternocleidomastoid-rectus abdominus line
    - Overlies medial side of pectoralis major. Arises from sternum.
- **Lymphatic Malformation**
  - Unilocular/multilocular
  - Anechoic compressible cysts with thin walls and intervening septa
  - No vascularity demonstrated
  - Hemorrhage or infection leads to irregular walls, internal debris with fluid-fluid level and thick septa
- **Vascular Malformation**
  - Hypoechoic with heterogeneous echo pattern with dilated channels
  - Phleboliths seen as focal echogenic foci with dense posterior shadowing
  - Characterized as slow flow or high flow
    - Capillary, venocapillary, venous, or arteriovenous
  - Slow-moving (''to and fro'') blood with red cell aggregates better seen on grayscale ultrasound
- **Abscess**
  - Cystic lesion with posterior acoustic enhancement
  - Adjacent inflammatory change
- **Sternoclavicular Joint Arthropathy**
  - Hypoechoic capsular thickening
  - Check for bone erosion, subluxation, crystals, and capsular hyperemia
  - CT usually helpful following initial ultrasound assessment
    - Better at classifying disease as osteoarthritis (common), inflammatory arthritis (less common), crystal arthropathy (very uncommon), or septic arthritis (very uncommon)

Acute Rib Fracture



Oblique longitudinal ultrasound shows an undisplaced acute traumatic fracture ➔ of the echogenic anterior rib cortex with a small adjacent hematoma ➔.

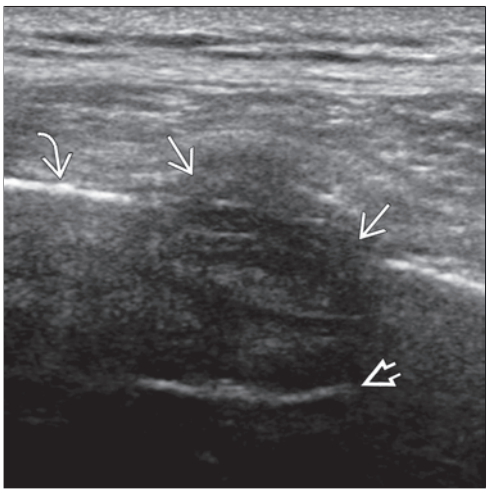
Healing Rib Fracture



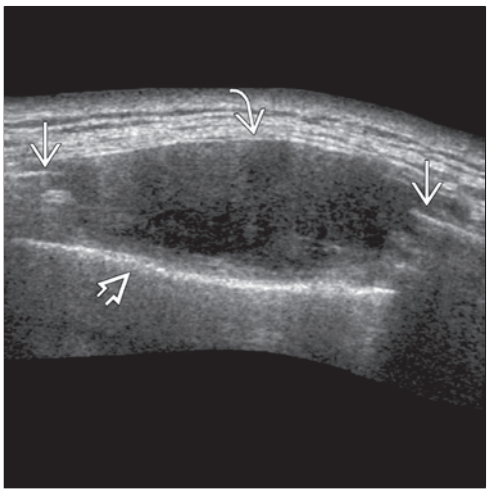
Longitudinal ultrasound shows a healing rib fracture with widened, rounded fracture margins ➔. Note the partially ossified ➔ callus around the fracture with mild peri-fracture soft tissue swelling ➔.

CHEST WALL LESION

Rib Metastases

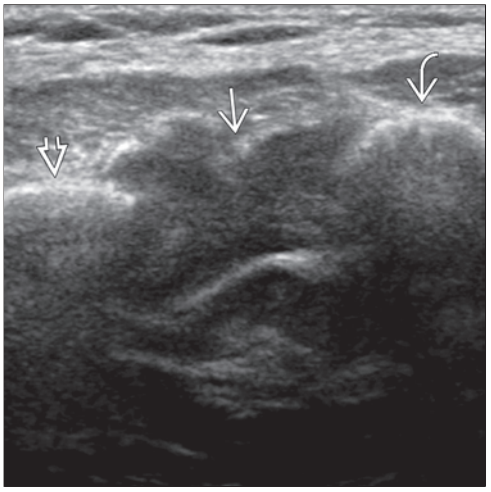


Rib Metastases

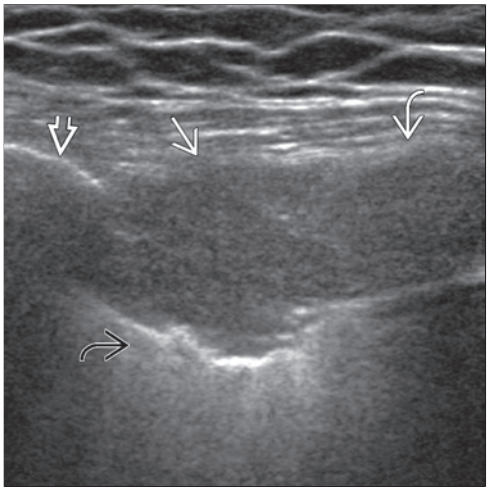


(Left) *Oblique longitudinal ultrasound shows a medium-sized, hypoechoic, metastatic deposit destroying the anterior cortex of the rib and providing an acoustic window to view the underlying pleura. Mild extraosseous soft tissue extension is present.* ***(Right)*** *Longitudinal ultrasound shows a large, hypoechoic, metastatic deposit focally replacing the rib and providing an acoustic window to view the underlying pleura.*

Muscle Metastases

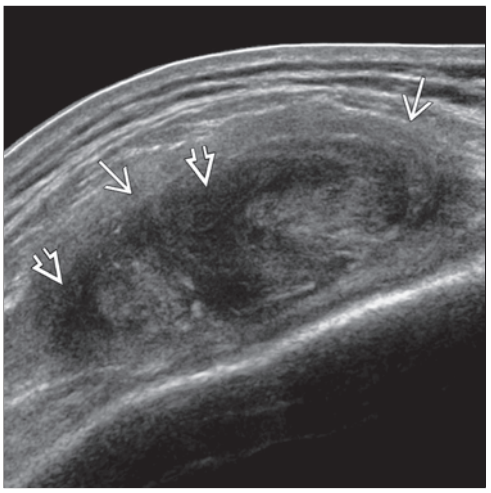


Muscle Metastases

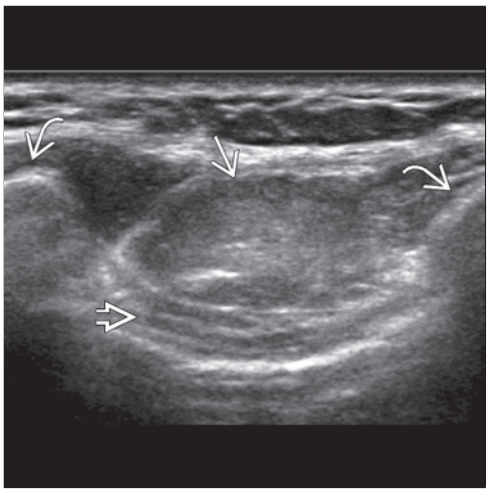


(Left) *Transverse ultrasound of the chest wall in a patient with known lung carcinoma shows a medium-sized hypoechoic mass with posterior enhancement between the right 5th and 6th ribs. Fine-needle aspiration confirmed metastatic lung carcinoma.* ***(Right)*** *Transverse ultrasound of the chest wall shows a medium-sized hypoechoic mass between the hypoechoic 2nd costal cartilage and the 3rd rib. The indented pleura moved freely on real-time imaging.*

Hematoma

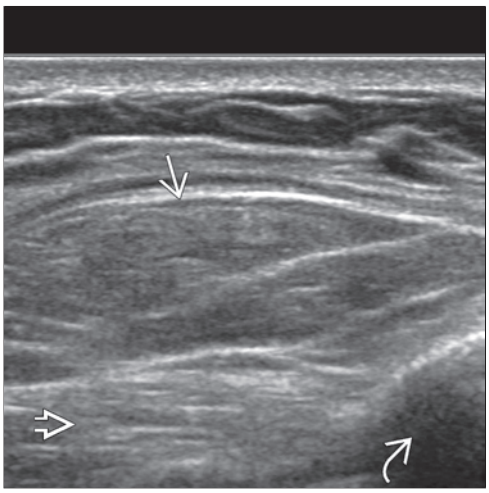


Hematoma

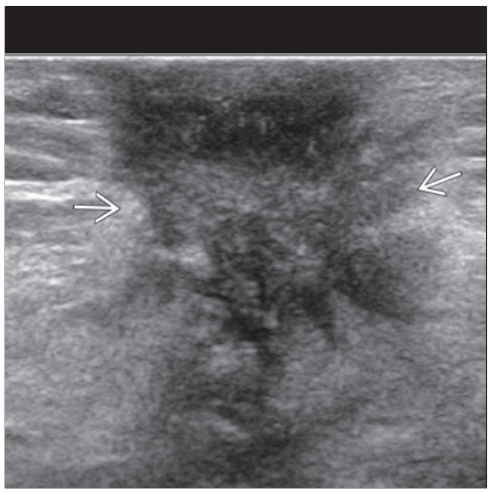


(Left) *Oblique longitudinal ultrasound shows a large organizing hematoma within the latissimus dorsi muscle overlying the posterior aspect of a rib. The hypoechoic component of the hematoma is due to early liquefaction.* ***(Right)*** *Transverse ultrasound following recent trauma shows a slightly hypoechoic, well-defined acute hematoma between 2 ribs. The intercostal muscle is displaced deep to the hematoma. There was no associated rib fracture.*

Lipoma

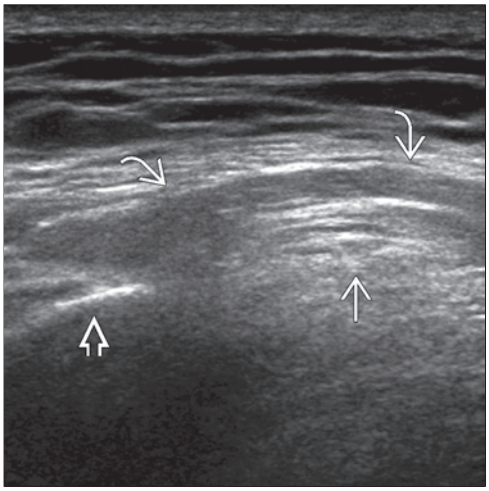


Fibroma

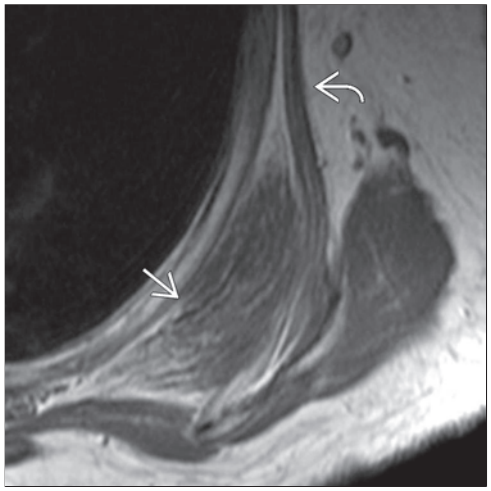


(Left) *Transverse ultrasound shows an intramuscular lipoma within the pectoralis major muscle. An anterior part of a rib is also shown.* ***(Right)*** *Transverse ultrasound shows a cutaneous and subcutaneous fibroma in the axillary region. The edges of the typically hypoechoic mass interdigitate with the surrounding fat.*

Elastofibroma Dorsi

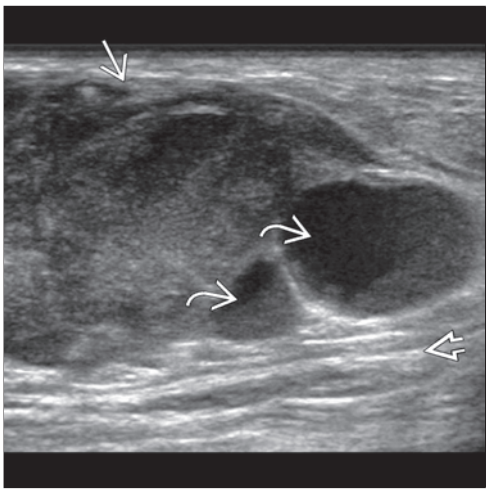


Elastofibroma Dorsi

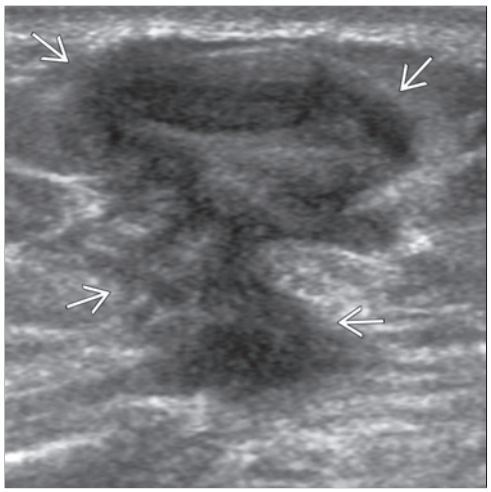


(Left) *Transverse ultrasound of the infrascapular region in an elderly woman shows a mixed echogenic mass overlying the rib and a moderately atrophic latissimus dorsi muscle. The mass is composed of hypoechoic (fat) and hyperechoic (fibrous) strands consistent with elastofibroma.* ***(Right)*** *Axial T1WI MR of the same patient shows a crescent-shaped mass deep to the latissimus dorsi comprised of hyperintense (fat) and hypointense (fibrous) strands.*

Carcinoma, Male Breast



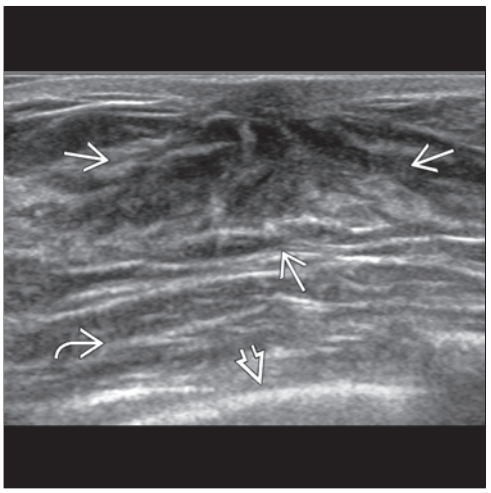
Carcinoma, Male Breast



(Left) *Transverse ultrasound shows a heterogeneous, mixed solid/cystic mass with distinct margins, associated with edema and architectural distortion of the surrounding tissue. There is mild posterior acoustic enhancement. Note the cystic component of the mass. Excision confirmed ductal carcinoma.* ***(Right)*** *Transverse ultrasound shows a more solid heterogeneous ductal carcinoma of the male breast with irregular lobulated margins.*

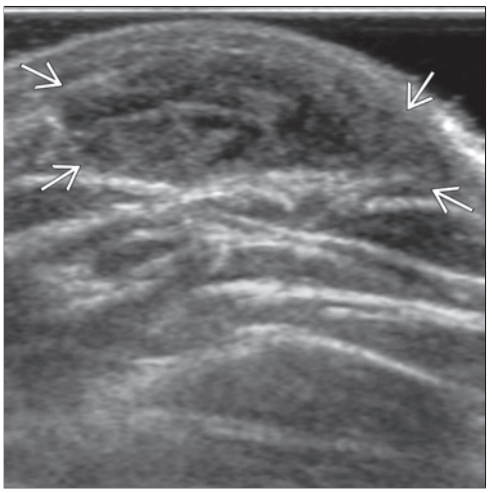
CHEST WALL LESION

Gynecomastia

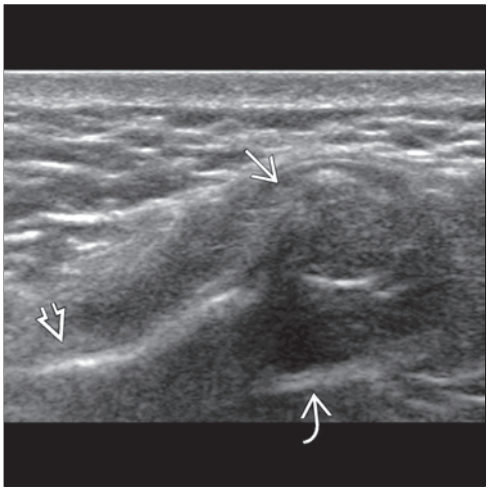


(Left) *Transverse ultrasound shows mild gynecomastia with an increase in subareolar hypoechoic fibrotic and fatty tissue. The underlying pectoralis muscle and rib is normal.* ***(Right)*** *Transverse ultrasound shows glandular breast tissue in the lower axillary region. Features are compatible with an accessory breast.*

Accessory Breast

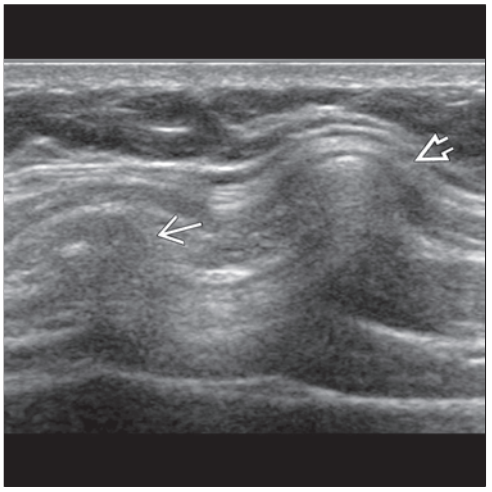


Prominent Xiphoid Process

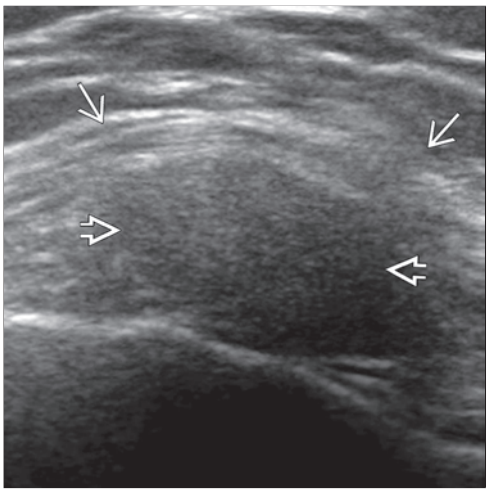


(Left) *Longitudinal ultrasound in a young patient with an epigastric mass shows a prominent forward-protruding hypoechoic xiphoid process at the lower end of the sternum and overlying the peritoneum.* ***(Right)*** *Transverse ultrasound in a patient with a lower chest wall mass shows a protruding 12th rib, which is more superficially positioned than the adjacent 11th rib. Both ribs were otherwise normal.*

Prominent Rib

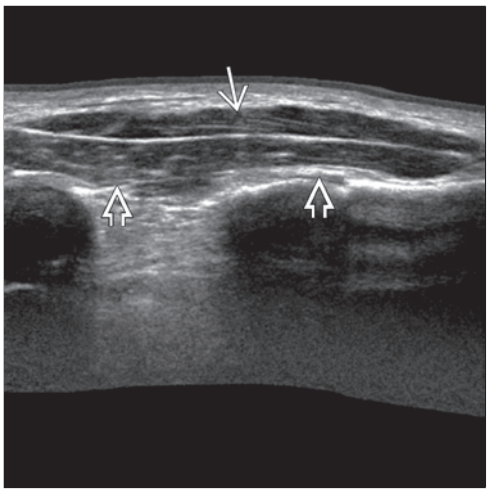


Costochondritis

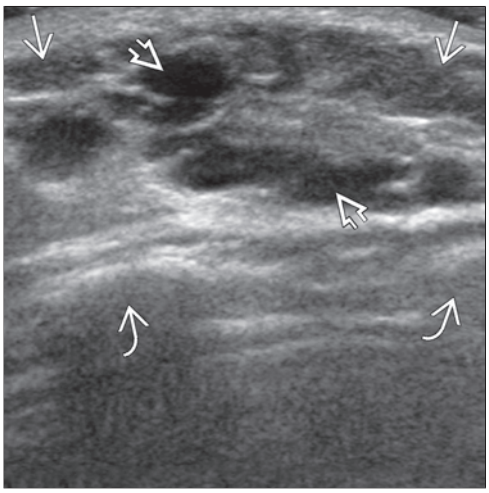


(Left) *Transverse ultrasound in a patient with anterior chest wall pain shows moderate swelling of the 2nd costal cartilage. There is mild edema indicative of inflammatory change surrounding the swollen costal cartilage. There was also probe tenderness. Features are consistent with costochondritis.* ***(Right)*** *Longitudinal ultrasound in a patient with asymmetric swelling of the anterior chest wall shows an accessory muscle superficial to the pectoralis major muscle.*

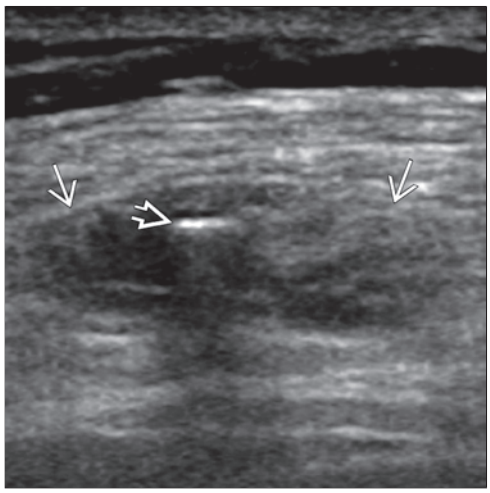
Accessory Muscle



Lymphatic Malformation

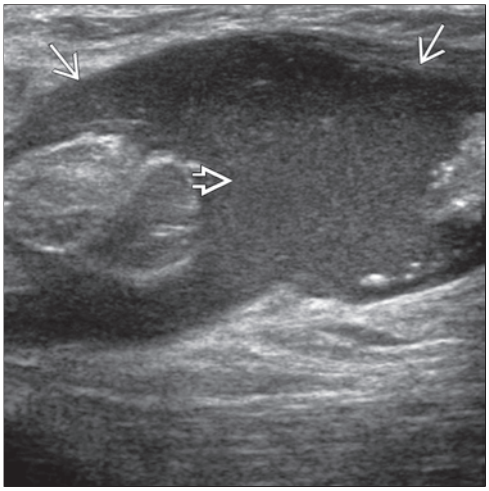


Vascular Malformation

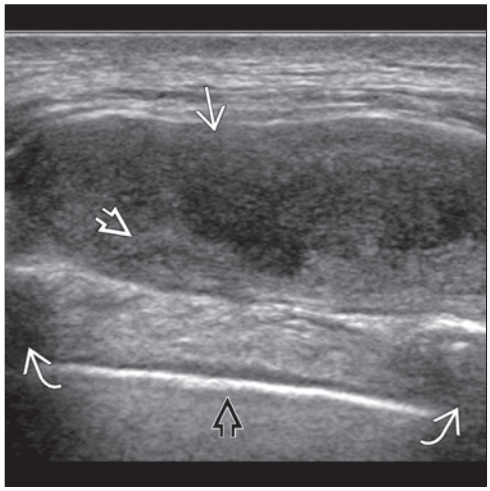


(Left) *Longitudinal ultrasound of the chest wall shows a poorly defined lymphatic malformation of the lower anterior chest wall with a cystic component and poorly defined swollen supporting stroma. The underlying rib is normal. Color Doppler imaging (not shown) showed no internal vascularity within the lesion.* ***(Right)*** *Transverse ultrasound of the chest wall shows a venous-type vascular malformation with a small phlebolith.*

Abscess

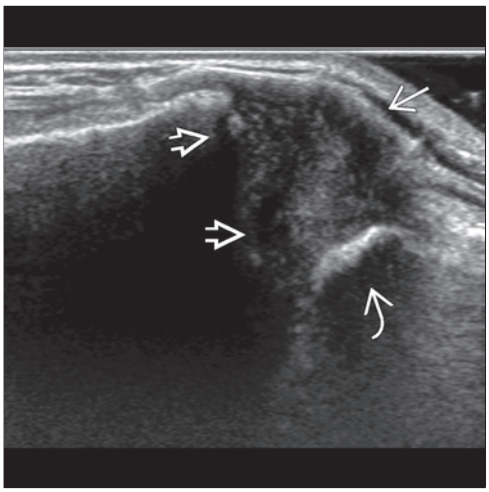


Abscess



(Left) *Transverse ultrasound shows a recurrent chronic abscess in the subcutaneous tissues of the lower lateral chest wall. Note fine internal echoes within the collection. Ultrasound-guided aspirate yielded Staphylococcus aureus.* ***(Right)*** *Oblique ultrasound shows a chronic abscess in the upper lateral chest wall with thickened inflammatory-type tissue. The pleura deep to the rib interspace is normal.Ultrasound-guided aspirate yielded Streptococcus pyogens.*

Sternoclavicular Joint Arthropathy



Sternoclavicular Joint Arthropathy



(Left) *Oblique ultrasound in RA patient shows moderate inflammatory arthritis of the sternoclavicular joint with prominent capsular thickening and mild erosion of the medial end of clavicle. The manubrium is not eroded. Ultrasound is good, though CT is better, at discriminating the various forms of sternoclavicular swelling.* ***(Right)*** *Photograph of the same patient shows how sternoclavicular joint swelling is easily visible clinically since it lies just beneath the skin.*

ABDOMINAL WALL MASS

DIFFERENTIAL DIAGNOSIS

Common
- Subcutaneous Lipoma
- Incisional Hernia
- Linea Alba Hernia
- Inguinal Hernia

Less Common
- Spigelian Hernia
- Lumbar Hernia
- Paraumbilical Hernia
- Umbilical Hernia
- Endometrioma
- Undescended Testis
- Enlarged Lymph Node
- Rectus Sheath Hematoma
- Subcutaneous Hematoma
- Fat Necrosis
- Desmoid Tumor
- Muscle Tear
- Diastasis Recti
- Nerve Sheath Tumor
- Intramuscular lipoma
- Abscess
- Granuloma

ESSENTIAL INFORMATION

Key Differential Diagnosis Issues
- Pay close attention to deep margin of any anterior abdominal wall mass because hernias may masquerade as abdominal wall masses
  - Defect may be small relative to size of mass & potentially overlooked
  - Hernia mass may be fixed & not reducible
  - May look like hypoechoic subcutaneous nodule or lipomatous mass
  - Check for peristalsis, vascularity, & perform Valsalva maneuver
    - Valsalva for groin hernia is often better with patient standing upright
  - If deep border of mass is not seen, reassess with either CT or MR

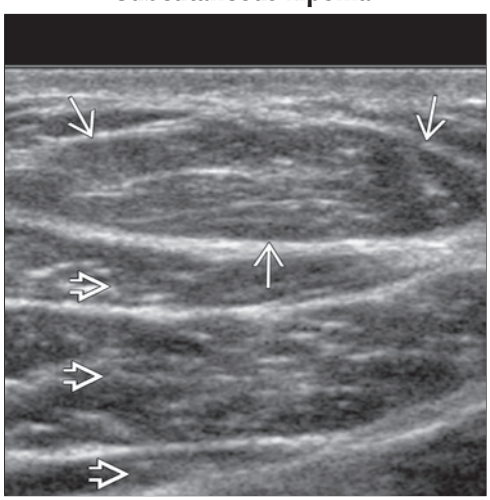
Helpful Clues for Common Diagnoses
- **Subcutaneous Lipoma**
  - Often multiple & occur in middle age
  - Fusiform mass with thin, parallel, echogenic internal striations
    - Compressible similar to adjacent fat
  - Alternatively, well-defined, rounded or ovoid encapsulated echogenic mass without clearly definable linear fine striations
    - More common in abdominal wall than appendicular skeleton
- **Incisional Hernia**
  - Can occur after any abdominal operation
    - Presents months to years after surgery
- **Linea Alba Hernia**
  - Usually occurs in young to middle-aged patients
  - Protrusion of extraperitoneal fat through narrow defect in linea alba
    - Occurs where vessels perforate fascia
  - Small hernia containing either echo-poor or echogenic fat in epigastric region
    - Often no change with Valsalva, as neck of linea alba hernia is tight
  - Fatty contents can strangulate & infarct
- **Inguinal Hernia**
  - Indirect inguinal hernia is 4x more common than direct inguinal hernia
    - Direct inguinal hernia & femoral hernia have similar prevalence
  - Indirect hernia passes through deep inguinal ring, along inguinal canal, & out of superficial inguinal ring
    - Neck located lateral to inferior epigastric vessels & above inguinal ligament
    - Elongated oblique course
    - In males, follows course of spermatic cord to scrotum
    - In females, follows course of round ligament to labia majora
  - Direct hernia passes through floor of inguinal canal medially (transversalis fascia, Hesselbach triangle)
    - Neck located medial to inferior epigastric vessels & above inguinal ligament
    - Generally smaller than indirect inguinal hernias
  - Femoral hernia passes through femoral canal
    - Neck located medial to femoral vein & below inguinal ligament
    - Narrow neck usually
    - More common in women
  - Ultrasound can accurately identify presence, type, & content of groin hernia
    - Content includes fat, omentum, fluid, & bowel
    - Omentum is echogenic due to omental fat & has no peristalsis
    - Bowel has visible bowel wall (± "target" echopattern) filled with fluid or bowel contents ± peristalsis

Helpful Clues for Less Common Diagnoses
- **Spigelian Hernia**
  - Defect in aponeurosis of transversus aponeurosis lateral to rectus sheath (linea semilunaris)
  - Most commonly located in lower abdomen ~ 1/3 way between umbilicus & pubic crest
    - Extends deep to external oblique aponeurosis
- **Lumbar Hernia**
  - Through defect in posterolateral abdominal wall
  - Spontaneous, postsurgical, or post-traumatic
  - Herniation of retroperitoneal fat ± colon or small bowel
- **Paraumbilical Hernia**
  - In adults
  - Protrudes through side of umbilical ring
  - Extraperitoneal fat ± peritoneal contents
- **Umbilical Hernia**
  - In young children
  - 1/3 of umbilical hernias close within 1 month of birth
  - Rarely persist beyond 3–4 years
  - Peritoneal content protrudes through patent umbilical ring
  - Large neck, therefore unlikely to strangulate
- **Endometrioma**
  - Palpable mass often near cesarean section scar or pelvic surgical scar
  - Pain ± cyclical pain occurring with menses

- Solid, mainly hypoechoic, heterogeneous nodule
- Infiltrating margins
- Peripheral hyperechoic ring
- Mild internal vascularity
- Anechoic cystic areas uncommon

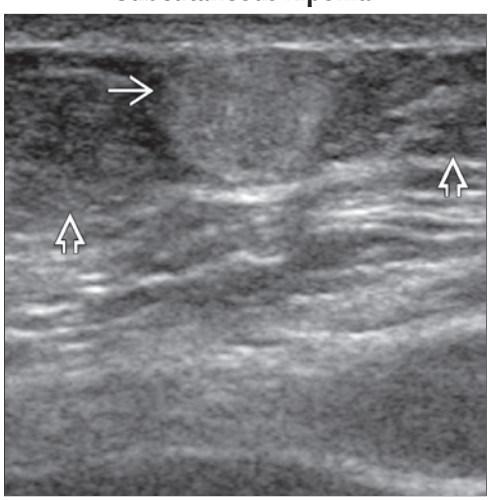
- **Undescended Testis**
  - Ultrasound will locate undescended testis in nearly 90% of patients with cryptorchidism
    - 90% of undescended testes located in inguinal canal
    - Remainder located in abdomen & pelvis
- **Enlarged Lymph Node**
  - Subcutaneous mass or masses near inguinal ligament
  - Features of reactive node or malignant node
  - Hilar or capsular vascularity on color Doppler
- **Rectus Sheath Hematoma**
  - Due to bleeding within rectus sheath from injury to superior or inferior epigastric arteries or direct tear of rectus muscle
  - Inferior epigastric artery arises from external iliac artery
    - Ascends between rectus abdominis muscle & posterior rectus sheath
    - Prone to injury during strong muscle contractions
  - Superior epigastric artery originates from external thoracic artery
    - Descends between rectus abdominis muscle & posterior rectus sheath
- **Subcutaneous Hematoma**
  - Post-traumatic (typical) or spontaneous (uncommon) due to bleeding of subcutaneous vessel
- **Fat Necrosis**
  - Localized increased echogenicity of subcutaneous fat with loss of normal fat striation
  - Irregular poorly defined margins without discrete mass
  - ± localized swelling ± lobulation of subcutaneous fat due to edema
  - Affected fat area becomes better defined & more hypoechoic with increasing chronicity
  - ± fluid accumulation within affected fat
  - ± calcification of affected fat
- **Desmoid Tumor**
  - Benign fibrous tumor also known as fibromatosis with predilection for anterior abdominal wall
    - Hypoechoic tumor often with irregular margin
- **Muscle Tear**
  - Affects oblique muscles in lower abdominal quadrants
    - Well-localized mechanical pain
    - Affects athletes & patients with chronic cough
- **Diastasis Recti**
  - Results from widened linea alba
  - Ultrasound to exclude presence of true ventral hernia
- **Nerve Sheath Tumor**
  - Fusiform, hyperemic, hypodense mass ± myxoid areas ± internal hemorrhage
- **Intramuscular Lipoma**
  - Intramuscular or intermuscular location
  - Similar appears to subcutaneous lipoma
  - Echogenic mass with fine linear striations parallel to long axis of tumor
  - Increasing size or atypical features increase likelihood of malignancy
- **Abscess**
  - Posterior enhancement characteristics
  - Depending on maturity & content, echogenicity of fluid may vary from hypoechoic to isoechoic to hyperechoic
    - May mimic solid mass if thick fluid/debris is present → low threshold for aspiration as fluid is not readily discernible
  - Echo movement on real-time imaging
  - Wall thickness proportional to chronicity of abscess
  - ± gas locules
    - → "comet tail" artifacts or larger shadowing artifact
  - ± septations
  - ± peripheral hyperemia
- **Granuloma**
  - May arise from retained suture, injection, or chronic infection
  - Hypoechoic mass ± suture material ± mild to moderate vascularity

Subcutaneous Lipoma



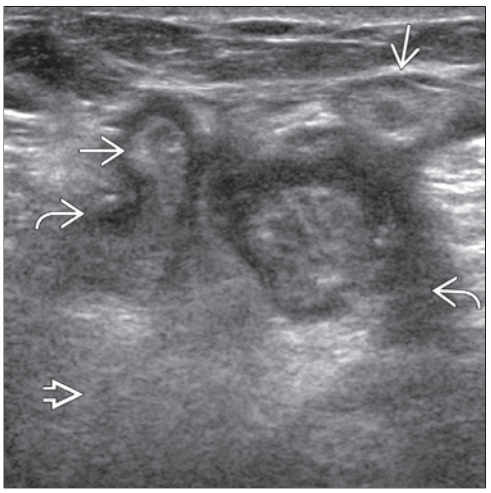
Transverse ultrasound shows a subcutaneous lipoma ➔ in the lateral abdominal wall. The external oblique, internal oblique, & transversalis abdominal wall muscles ➔ are not involved.

Subcutaneous Lipoma

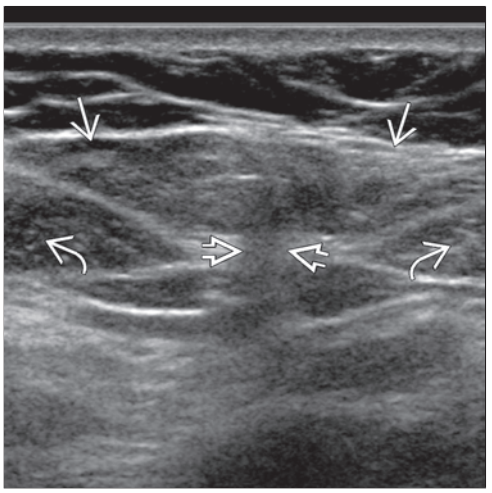


Transverse ultrasound shows a small rounded echogenic subcutaneous lipoma ➔ in the anterior upper abdominal wall. The lipoma is distinctly echogenic relative to the adjacent hypoechoic subcutaneous fat ➔.

Incisional Hernia

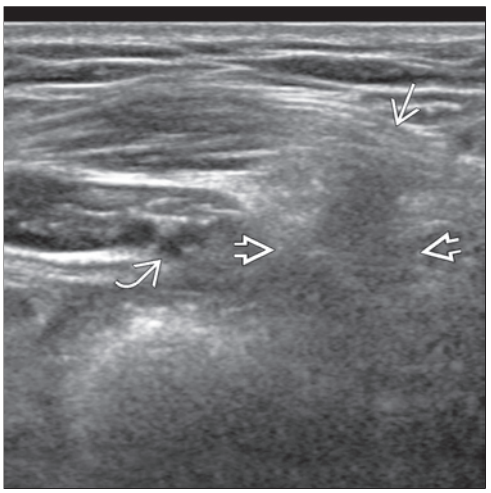


Linea Alba Hernia

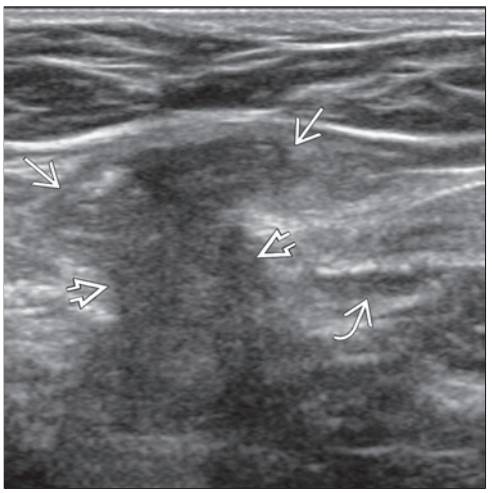


(Left) *Transverse ultrasound shows loops of small bowel protruding from the peritoneal cavity into the subcutaneous fat through a wide incisional fascial defect in the lower abdomen.* ***(Right)*** *Transverse ultrasound shows a linea alba hernia extending through a narrow defect in the linea alba between the rectus muscles in the upper abdomen. The sac contains hypoechoic mesenteric fat & no bowel.*

Inguinal Hernia

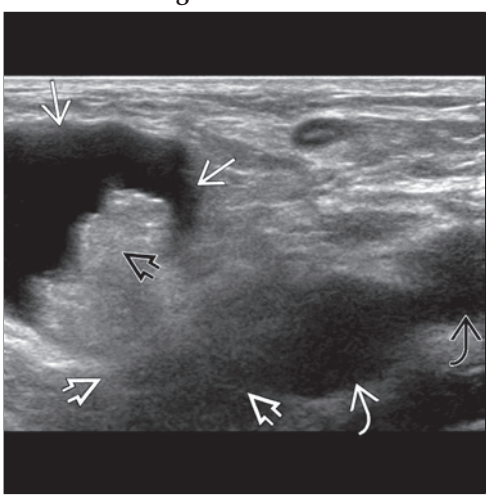


Inguinal Hernia

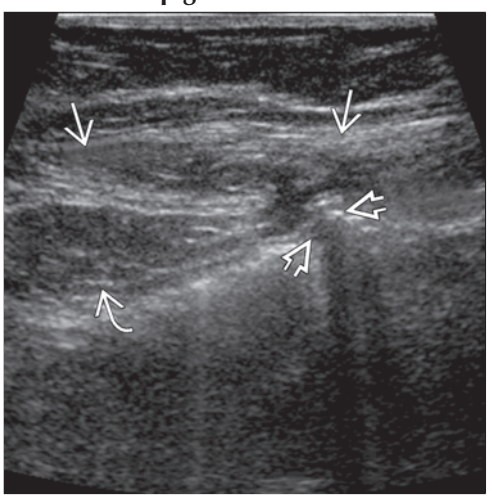


(Left) *Transverse ultrasound shows an indirect inguinal hernia. The neck of the hernia lies above the inguinal ligament & lateral to the inferior epigastric vessels. The sac contains mesenteric fat.* ***(Right)*** *Transverse ultrasound shows a direct inguinal hernia. The neck of the hernia lies above the inguinal ligament & medial to the inferior epigastric vessels. The sac contains fluid & omentum.*

Inguinal Hernia

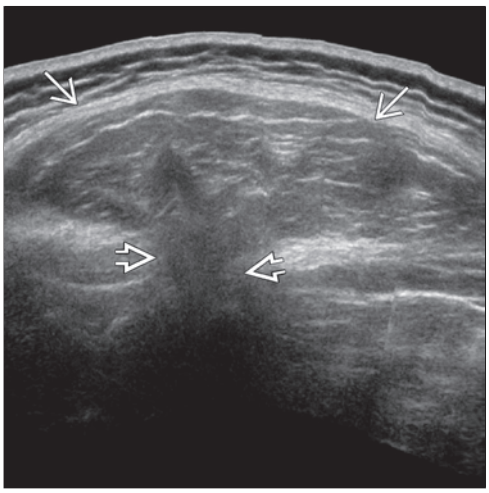


Spigelian Hernia

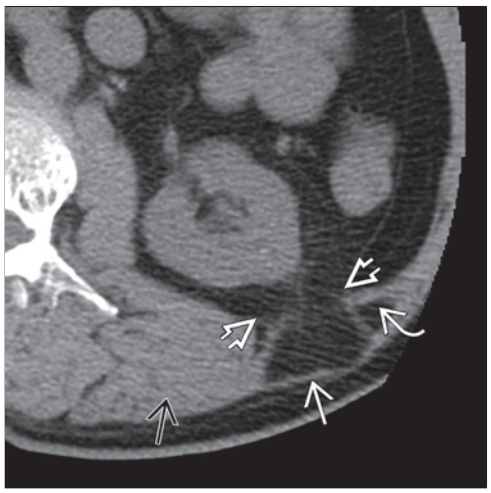


(Left) *Transverse ultrasound shows a femoral hernia. The neck of the hernia lies below the inguinal ligament & medial to the femoral vein. The hernia sac contains fluid with a segment of small bowel. The femoral artery is also shown.* ***(Right)*** *Transverse ultrasound shows a spigelian hernia extending through a defect in the linea semilunaris, which is at the lateral border of the rectus muscle in the lower abdomen. The sac contains mesenteric fat.*

Lumbar Hernia

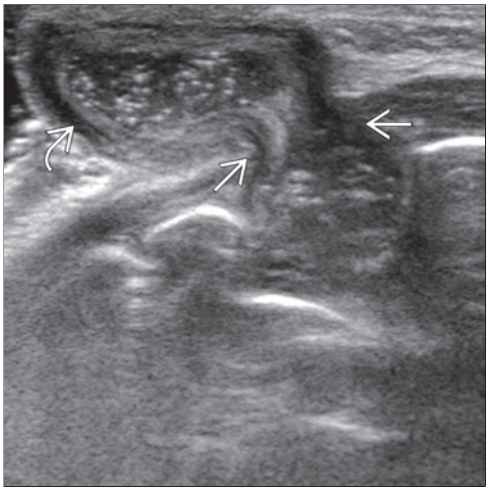


Lumbar Hernia

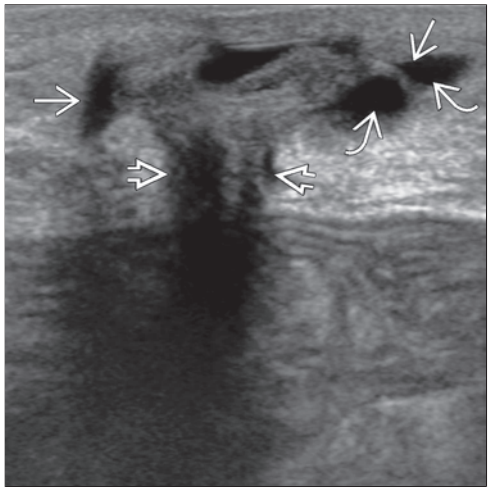


(Left) *Oblique ultrasound shows a wide defect in the fascia of the posterior abdominal wall with herniation of retroperitoneal fat through this defect.* ***(Right)*** *Axial NECT of the same patient shows the large fascial defect posterior to the left kidney. The hernia sac contains retroperitoneal fat. The defect is bounded by the erector spinae muscle medially and the retracted quadratus lumborum muscle laterally.*

Umbilical Hernia

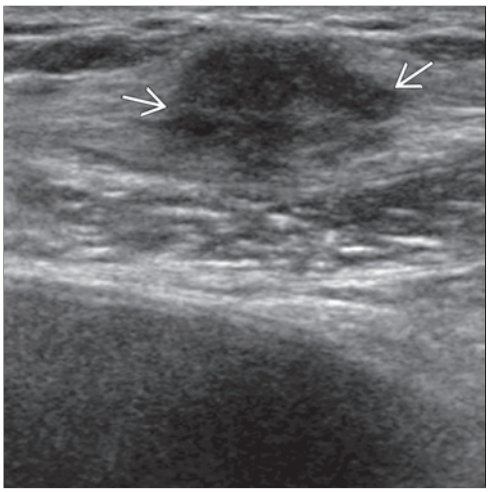


Umbilical Hernia

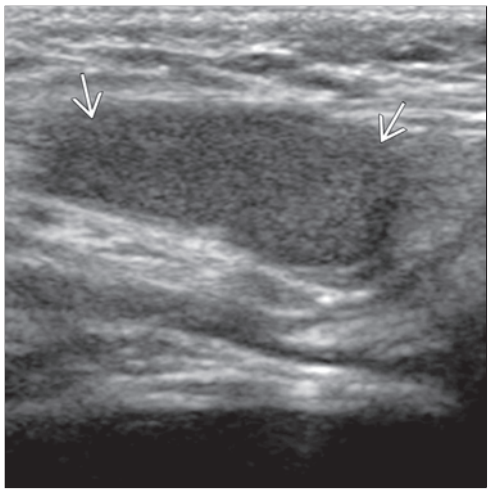


(Left) *Transverse ultrasound shows bowel protruding though the umbilicus in this newborn with an umbilical hernia. The neck of this type of hernia is wide, allowing the hernia to be easily reduced and thereby not prone to strangulation.* ***(Right)*** *Transverse ultrasound shows an umbilical hernia extending through a defect in the umbilicus. The sac contains fluid and mesenteric fat.*

Endometrioma



Undescended Testis

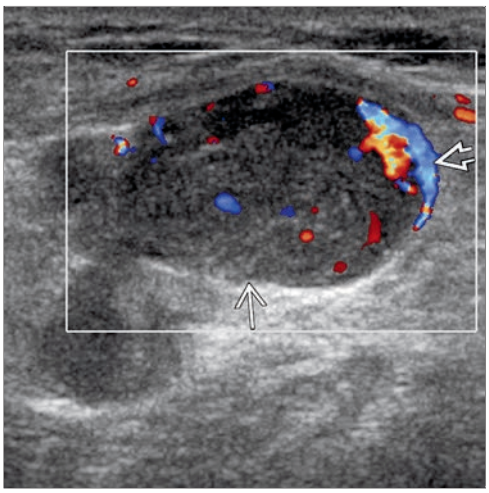


(Left) *Transverse ultrasound shows a heterogeneous, mildly irregular, hypoechoic mass in the subcutaneous region of the lower anterior abdominal wall close to a cesarean section scar.* ***(Right)*** *Transverse ultrasound shows an oval-shaped hypoechoic testis within the inguinal canal in a patient with cryptorchidism. Most undescended testes are located in the inguinal canal.*

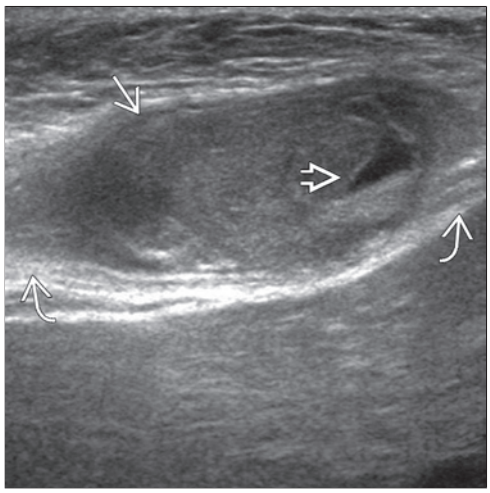
ABDOMINAL WALL MASS

Enlarged Lymph Node

(Left) *Transverse color Doppler ultrasound of the groin shows an enlarged rounded metastatic lymph node from a primary uterine carcinoma. There is loss of the normal fatty hilum with a predominantly peripheral capsular vascularity.* ***(Right)*** *Transverse ultrasound shows a large traumatic hematoma within an edematous rectus abdominis muscle. The hematomas are contained by the rectus sheath. There is small area of liquefaction.*

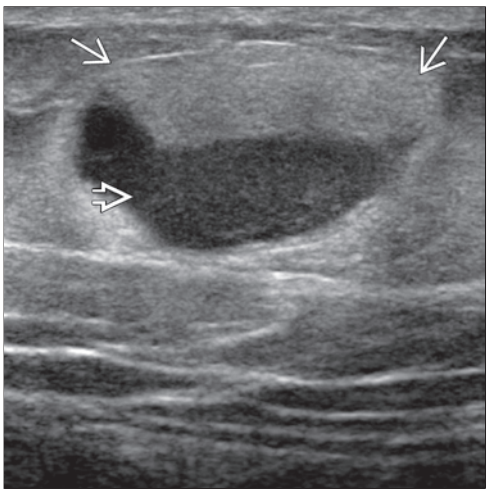


Rectus Sheath Hematoma

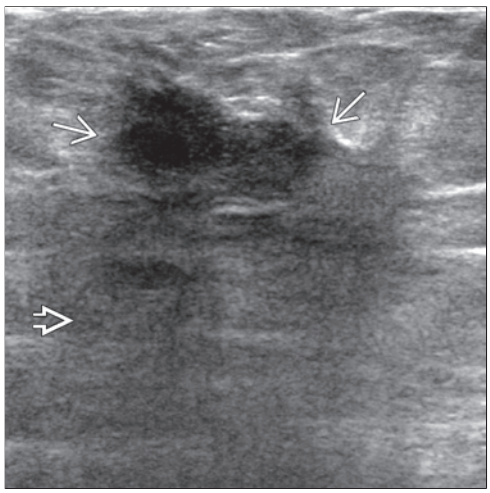


Subcutaneous Hematoma

(Left) *Transverse ultrasound shows a subcutaneous hematoma in the lateral abdominal wall. There is a large area of liquefaction within the hematoma.* ***(Right)*** *Transverse ultrasound shows an ill-defined hypoechoic subcutaneous mass in the lateral abdominal wall. Mild liquefaction is present. There is posterior acoustic shadowing. Biopsy of the mass confirmed fat necrosis. As is commonly the case, there was no recall of any abdominal trauma.*

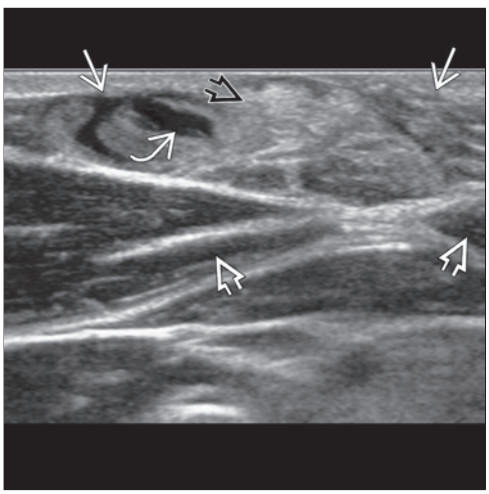


Fat Necrosis

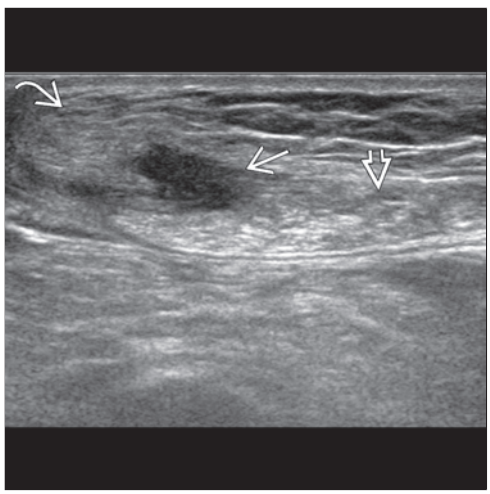


Desmoid Tumor

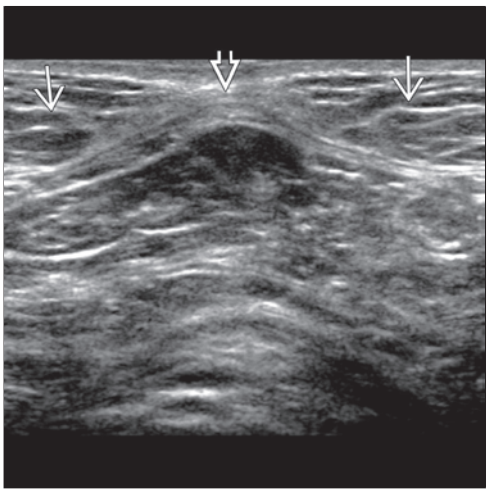
(Left) *Transverse ultrasound shows a large extensive subcutaneous desmoid tumor in the anterior abdominal wall superficial to the rectus muscles. The tumor is heterogeneous with hyperechoic and cyst-like components.* ***(Right)*** *Transverse ultrasound shows a focal superficial tear of the rectus abdominus muscle. There is focal hematoma filling the tear. Note the adjacent subcutaneous edema.*



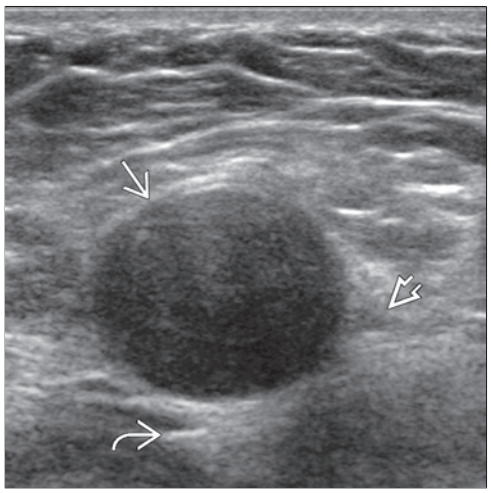
Muscle Tear



Diastasis Recti

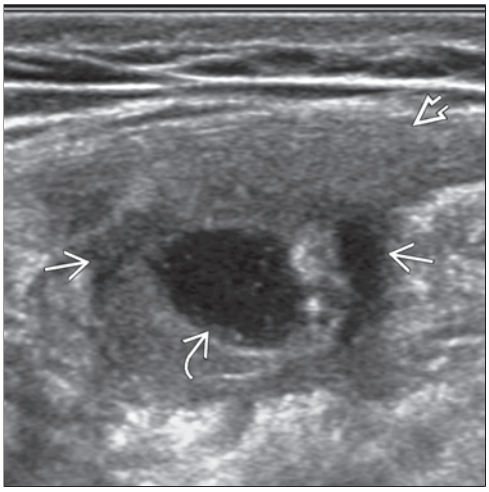


Nerve Sheath Tumor

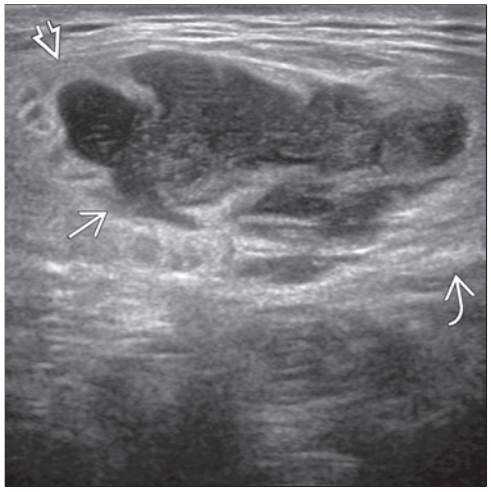


(Left) *Transverse ultrasound shows a widened linea alba* ➔ *connecting the rectus abdominus muscles* ➔*. The widened linea alba is bulging upwards in the midline, simulating a hernia. No fascial defect or hernia is present.* ***(Right)*** *Transverse ultrasound shows a well-defined nerve sheath tumor* ➔ *in the subcutaneous region of the lateral abdominal wall. There is posterior acoustic enhancement* ➔*. There is a possible thickened subcutaneous nerve* ➔ *at one margin of the tumor.*

Abscess

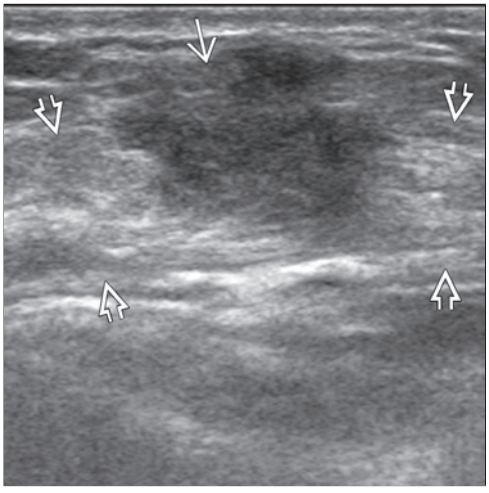


Abscess

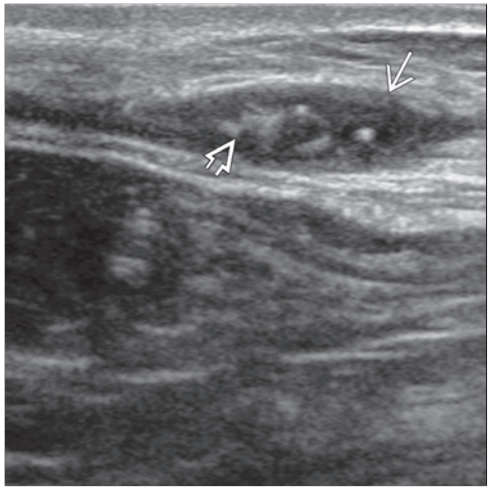


(Left) *Transverse ultrasound shows a subacute abscess* ➔ *in the lateral abdominal wall with adjacent inflammatory/reparative change* ➔*. Note the drainable fluid component* ➔*. Ultrasound-guided aspiration yielded Staphylococcus aureus.* ***(Right)*** *Transverse ultrasound shows a recurrent chronic abscess* ➔ *in the lateral abdominal wall. The abscess wall* ➔ *is thickened with moderate surrounding subcutaneous edema* ➔*. Ultrasound-guided aspiration yielded gram-negative bacilli.*

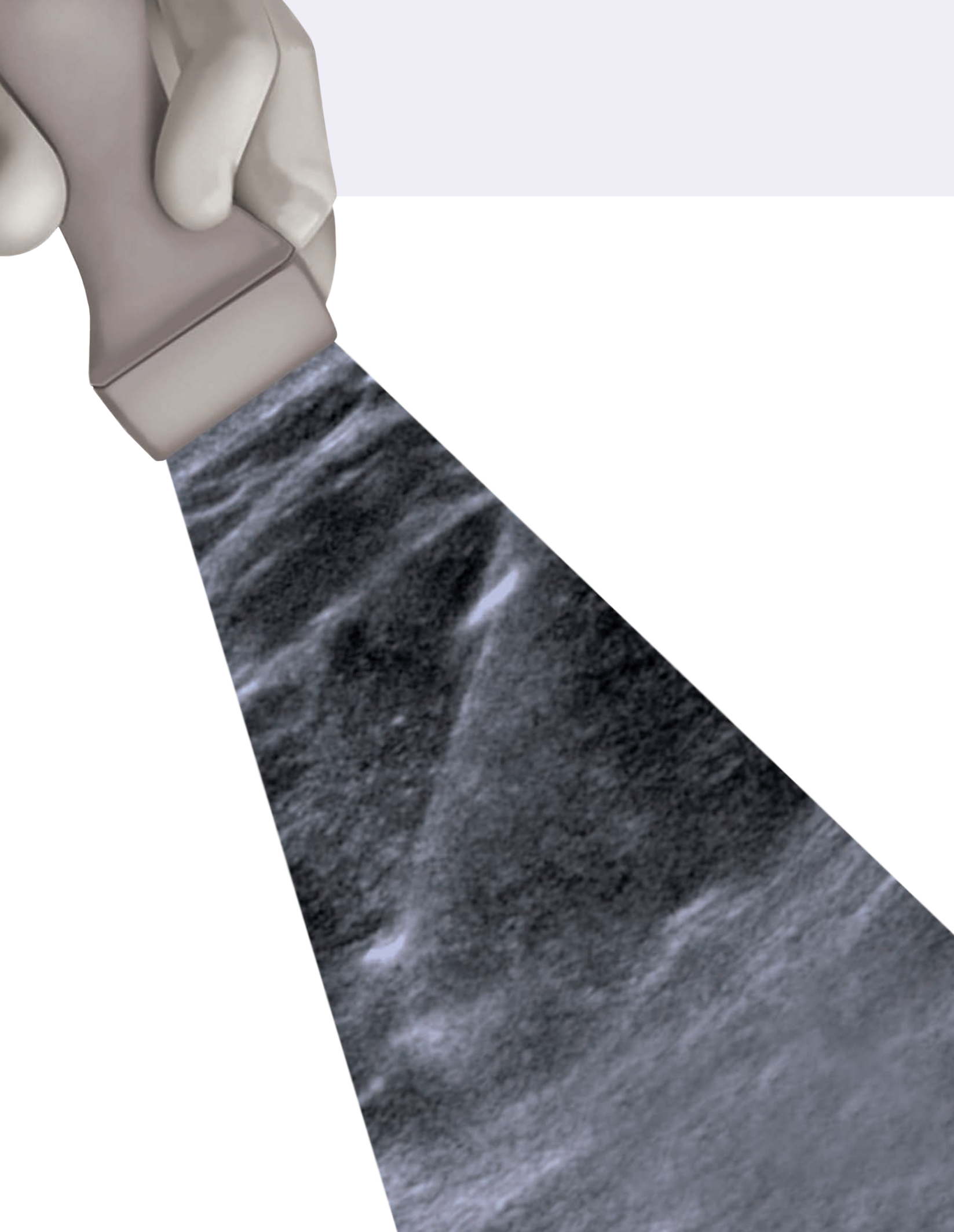
Granuloma



Granuloma



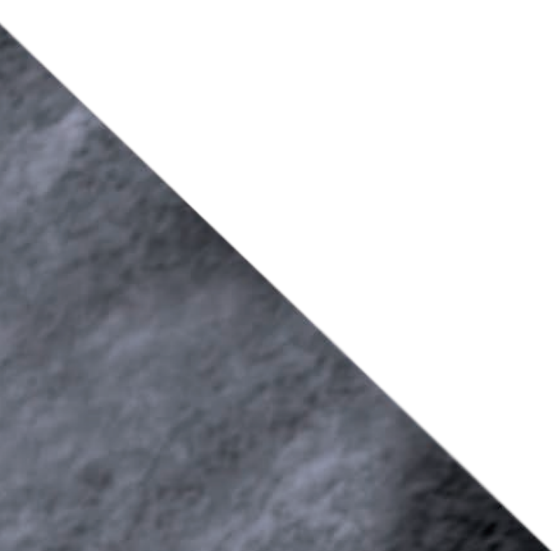
(Left) *Transverse ultrasound shows a hypoechoic postoperative granuloma* ➔ *within the moderately atrophic, echogenic abdominal wall musculature* ➔*. The granuloma is typical with an ill-defined irregular border.* ***(Right)*** *Longitudinal ultrasound shows a small stitch granuloma* ➔ *in the deep subcutaneous tissues of the anterior abdominal wall. There is hyperechoic suture material* ➔ *within the hypoechoic granuloma.*



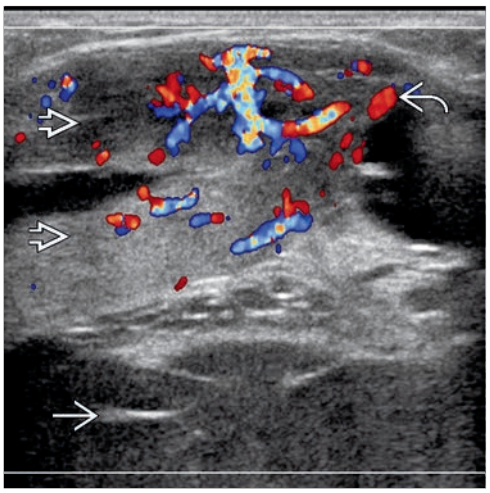
SECTION 1

Biopsy

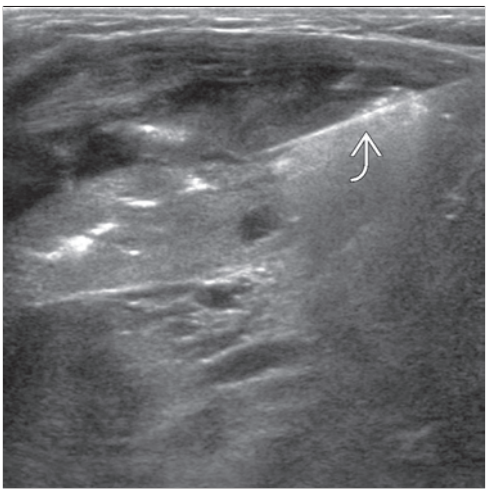
Biopsy Soft Tissue Tumor **IV**-1-2
Biopsy Bone Tumor **IV**-1-8



BIOPSY SOFT TISSUE TUMOR



Transverse color Doppler ultrasound shows a mixed solid-cystic soft tissue mass in the arm. Moderate tumor vascularity is present within the solid component surrounding the cystic component.



Transverse ultrasound shows the biopsy needle within the solid component. The biopsy path should be planned with a view to biopsy this solid area. Histology revealed a biphasic synovial sarcoma.

TERMINOLOGY

Abbreviations

- Fine-needle aspiration for cytology (FNAC)

Definitions

- Percutaneous biopsy of soft tissue tumor under ultrasound guidance
  - Accurate, safer, and more cost-effective alternative to open biopsy for tissue diagnosis

PRE-PROCEDURE

Indications

- Establish specific histological diagnosis of a soft tissue mass lesion with indeterminate imaging findings
- Confirmation & tumor typing of suspected soft tissue sarcoma
- Confirm or exclude musculoskeletal metastases in patient with known primary tumor
- Confirm or exclude tumor recurrence in patient with prior tumor resection
- Provide tissue for histological analysis and bacteriological culture in patient with suspected soft tissue infection
- Provide tissue for histological analysis in patient with suspected inflammatory myositis

Contraindications

- Uncorrected bleeding diathesis
- Uncooperative patient
- Site inaccessible to ultrasound access
- Soft tissue mass too small for percutaneous biopsy
  - Lesions < 1 cm in diameter are generally not amenable to percutaneous biopsy
  - FNAC is more appropriate for these smaller masses
- High-flow vascular anomaly or tumour in site inaccessible to post-biopsy tamponade
  - Most highly vascularized tumors can be safely biopsied provided they are located in area where adequate percutaneous tamponade can be applied post biopsy

Getting Started

- Things to check
  - Time-out procedure (patient's identity, type of procedure, side of procedure)
  - Signed informed consent
  - If patient taking anticoagulants, optimize clotting profile before procedure
    - How stringently this is applied depends on perceived difficulty in applying adequate percutaneous tamponade post biopsy
  - Sedation rarely required
    - Resuscitation facilities should be available
  - Review prior imaging
    - Accurate specific imaging diagnosis may be made in a large number of soft tissue masses, negating need for percutaneous biopsy
    - Sensitivity/specificity of ultrasound for diagnosis of superficial soft tissue tumors is high
      - 95%/94% for lipoma
      - 80%/95% for epidermoid cyst
      - 73%/98% for vascular malformation
      - 69%/95% for nerve sheath tumor
    - There is no need to perform biopsy when you are sure of diagnosis based on imaging
      - Biopsy is unnecessary intervention
      - Biopsy is potentially hazardous and can be painful (e.g., if nerve sheath tumor is biopsied)
    - In other situations, e.g., distinguishing well-differentiated liposarcoma from lipoma, needle biopsy is generally not helpful
      - Histological examination of whole tumor mass is required
    - Plan suitable needle path and decide on area to be sampled, particularly targeting viable tumor area and avoiding neurovascular bundle
- Medications
  - Local anesthetic (2-3 mL 1% lignocaine) to skin
  - Sedation of anxious patient or young children
    - Intravenous midazolam or other benzodiazepine; antidote should be available
- Equipment list

BIOPSY SOFT TISSUE TUMOR

Key Facts

Terminology
- Percutaneous biopsy of soft tissue tumor under ultrasound guidance

Pre-Procedure
- To determine nature and make a specific diagnosis of an indeterminate soft tissue mass
  - Biopsy not required in cases in which reliable specific diagnosis made by imaging alone
- High-frequency (7-12 MHz) linear array transducer
- Coaxial system preferred
  - 15-g coaxial needle with 16-g Tru-Cut needle

Procedure
- Ultrasound area of interest to best assess route and select viable areas of lesion before biopsy
  - Target solid area, preferably with evidence of neovascularization on color Doppler
  - Avoid cystic or necrotic areas
- Avoid important intervening structures such as uninvolved compartment, neurovascular bundle, tendon, bowel, or other organs, especially in case of pelvic biopsy

Post-Procedure
- Local complication is very uncommon

Outcomes
- Occasionally, tissue obtained may not be representative of entire tumor
- Theoretical risk of tumor seeding along biopsy pathway
  - Risk much smaller than with open biopsy

- High frequency (7-12 MHz), linear array transducers should be used routinely
- Sterile biopsy set
- Biopsy needle type
  - Majority of percutaneous biopsies are performed using spring-loaded cutting needles
  - Tru-Cut needles employ an inner troughed needle, which is advanced into lesion, with outer cylindrical cuff isolating a core of tissue
  - End-cutting needles obtain tissue by isolating the core within end of advancing needle cylinder
- Biopsy needle size
  - Large core (14- to 18-g) biopsy needle
    - Larger biopsy needle provides more tissue for histology ensuring sufficient tissue is available for immunohistochemical staining & molecular studies
    - As risk of bleeding from easily compressible lesions is low, there is no advantage to using smaller needles for most musculoskeletal biopsies
  - Use finer needle (18- to 22-g) when risk of post-biopsy bleeding is significant (high-flow vascular tumor, tumor location not conducive to adequate percutaneous tamponade)
- Coaxial biopsy technique
  - Popular and efficient technique
  - Larger bore cannulated needle, which is placed into tumor under ultrasound guidance
    - Biopsy needle inserted through this outer coaxial needle into tumor
  - Coaxial needle 1-g larger than the Tru-Cut biopsy needle (e.g., 15-g coaxial needle, 16-g Tru-Cut needle)
  - Ability to obtain multiple cores using only 1 initial puncture
  - Better needle stability and time efficiency when multiple biopsies are taken
  - Reduces trauma to tissues along needle track, reduces likelihood of post-biopsy bleeding, and theoretically reduces risk of tumor seeding along biopsy tract
- Specimen bottles
  - Formalin or alcohol fixation
  - Specimen can also be sent fresh
  - Sterile bottle for microbiology

PROCEDURE

Patient Position/Location
- Variable, depending on lesion position
  - Make sure that both patient and radiologist are in a comfortable position

Procedure Steps
- Before performing biopsy, carefully scan region of interest to best assess route
- Must ensure that whenever possible compartmental integrity of tumor is maintained
  - Tissue planes can act as natural barriers to spread of tumor or infection
  - Some tissue planes have to be disrupted during biopsy
    - You cannot avoid going through subcutaneous compartment to biopsy muscle compartment
  - If tumor is located in 1 muscle compartment, do not, if at all possible, transgress another muscle compartment to reach this tumor
- Theoretical risk of seeding of tumor along needle tract in particular in case of sarcoma or other malignant tumors
  - In practice, with good technique, this risk is very low and much lower than with open biopsy
  - Biopsy tract has to be removed en bloc with tumor during surgery
  - Surgeon marks site of planned incision on skin with biopsy, whenever possible, being performed at this site
  - Keep the needle path within area of planned surgical resection
- Avoid important intervening structures
  - Particularly any neurovascular bundle or tendon, as well as bowel or peritoneal cavity in case of pelvic mass biopsy
  - Examine tissues proximal and distal to tumor to locate at-risk neurovascular bundle that may not be visible at biopsy site
- Select those tumor areas containing more viable representative tissue for sampling

- Identify solid viable areas using grayscale and color Doppler imaging
  - In general, tumor margins tend to provide more fruitful material than central area of tumor, which may be necrotic
  - If tumor is hypovascular, be certain to sample tumor margin
- Avoid cystic or necrotic areas as the yield will be nondiagnostic
- Hypervascular areas should be targeted rather than avoided since these most likely contain most metabolically active tumor tissue
  - Risk of bleeding is very low with single puncture and adequate tamponade

· Sterilize skin over planned area of puncture
· Place probe within a sterile probe cover
- Sterile transparent drape can be applied over ultrasound console to facilitate adjustment of control dials

· Test and load biopsy needle
· Inject local anesthetic
· Insert coaxial needle so that tip just pierces tumor capsule
· Insert core biopsy needle into coaxial needle
- Sample suitable areas
- Change direction of coaxial needle to sample different tumor areas
- In general, 3-4 biopsies are adequate
  - In friable tumors, ≥ 10 biopsies may be required
- May need more biopsies if only friable tissue is obtained
  - A single intact biopsy core is far better than multiple fragmented cores for pathological diagnosis
  - Length of biopsy core is more important than width

· Unload tissue cores into specimen bottle
- Adequate fixation is essential to preserve optimal histological and cytological features for proper pathological examination
- Minimal tissue handling
  - Tissue autolysis, crushing, drying, and handling artifacts may hinder morphological interpretation and limits certain immunohistochemical stains

· Rinse biopsy needle tip in normal saline before reinserting into coaxial needle
· Once sufficient biopsies have been obtained, remove coaxial needle and apply local pressure for hemostasis
· Procedure can usually be completed within 30 minutes as outpatient procedure
· Good sample size and tissue preservation optimize likelihood of correct pathological diagnosis
· **Fine-needle aspiration (FNA)**
- Local anesthesia is usually not necessary
- Usually use 21-g intravenous needle
- Provides cytology rather than histology in most circumstances
- Usually used in lymph nodes or small lesions
- Move needle "to and fro" within lesion with simultaneous rotational movement of needle
  - Rotational movement during FNAC is important to optimize cutting action
  - Apply constant gentle suction during FNAC
- Stop needle suction upon removing needle from lesion
- Spread aspirate onto specimen slides and fix immediately in 5 mL 95% alcohol solution
- Alternatively, inject aspirate into specimen bottle containing 5 mL 25% alcohol solution

Alternative Procedures/Therapies

· Surgical
- Open biopsy or excision

POST-PROCEDURE

Expected Outcome

· Uneventful in most circumstances
· Minimal wound discomfort
- Simple oral analgesics if wound pain

· Minimal bleeding curtailed by brief period (< 5 minutes) of local pressure for hemostasis
- Longer manual compression (~ 15 minutes) if tumor is highly hypervascular or with bleeding diathesis

Immediate Aftercare

· Apply simple dressing
- Dressing can be removed by patient the following day

· Monitor for ~ 1 hour in department for signs of bleeding (swelling, oozing, bruising)

Subsequent Aftercare

· Immediate strenuous exercise involving biopsied area
· Avoid water contact of biopsy site for 24 hours

OUTCOMES

Problems

· Occasionally, relatively small amount of tissue obtained may not be representative, especially in case of large tumor
- Success of procedure requires experienced pathologist working in close cooperation with radiologist

· Biopsy may not provide sufficient tissue for cytogenic analysis required to establish treatment protocol
· Percutaneous biopsy is a safe procedure with a very low complication rate

Complications

· Most feared complication(s)
- Neurovascular bundle injury or injury to vital organs
- Excessive bleeding

· Delayed complication(s)
- Infection and bleeding

· Risk of seeding of tumor along needle tract
- Biopsy tract has to be removed en bloc with tumor during surgery
- Plan biopsy path bearing in mind subsequent surgical track
- Risk of tumor seeding along tract is very low, especially if coaxial system is used rather than a single needle biopsy system

SELECTED REFERENCES

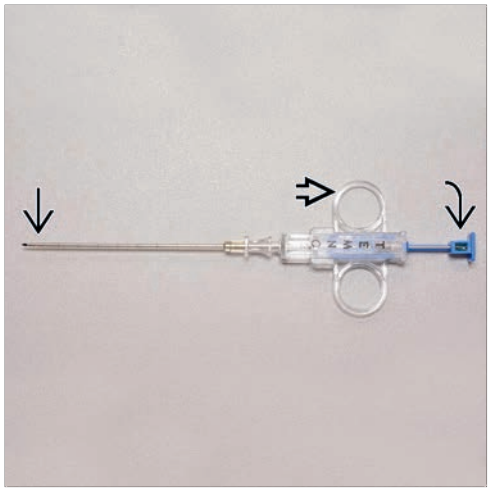
1. Didolkar MM et al: Image guided core needle biopsy of musculoskeletal lesions: are nondiagnostic results clinically useful? Clin Orthop Relat Res. 471(11):3601-9, 2013

BIOPSY SOFT TISSUE TUMOR

Biopsy Set

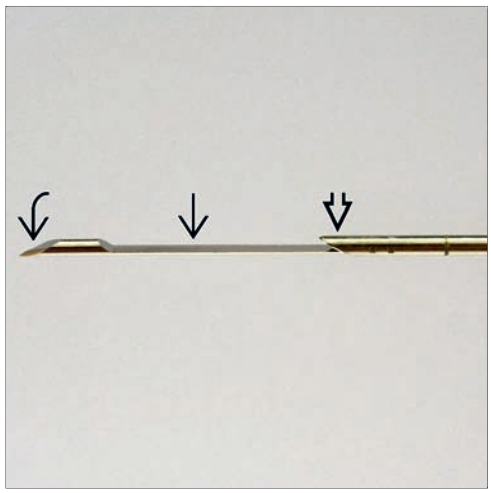


Tru-Cut Biopsy Needle

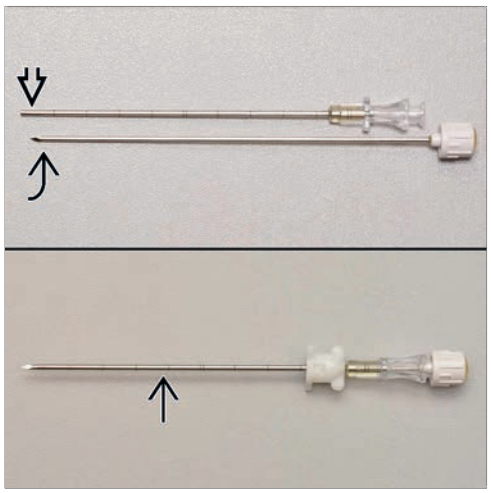


(Left) *Clinical photo of setup for soft tissue tumor biopsy shows the Tru-Cut biopsy needle, coaxial needle, syringe for local anesthetic, scalpel for skin incision, cleansing solution, and specimen bottle.* ***(Right)*** *Clinical photo of Tru-Cut biopsy needle shows a plunger for controlling the spring-activated mechanism, the handle, and the cutting cannula. The needle is in a loaded status.*

Tru-Cut Biopsy Needle

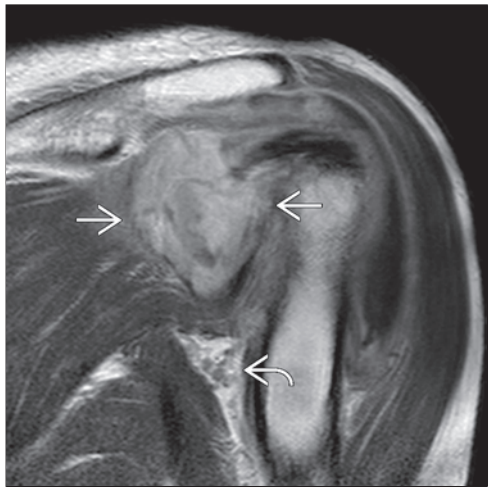


Coaxial Needle

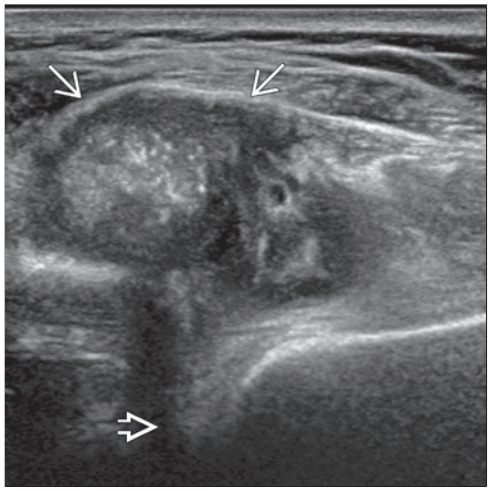


(Left) *Clinical photo shows an open Tru-Cut biopsy needle. Note the specimen slot and the sharp beveled needle tip. Pushing the plunger moves the outer cannula over the specimen slot, isolating a tissue sample.* ***(Right)*** *Clinical photo shows a coaxial needle. The outer cannula has a blunted end and an inner stylet with a sharp beveled tip. The stylet is placed inside the outer cannula during needle introduction. The coaxial technique allows multiple biopsies to be performed using a single puncture.*

Ultrasound-Guided Biopsy of Soft Tissue Tumor



Ultrasound-Guided Biopsy of Soft Tissue Tumor



(Left) *Coronal oblique T1WI C+ MR shows an enhancing synovial tumor arising from the glenohumeral joint. The enhancing soft solid component should be targeted, avoiding the neurovascular bundle, which is inferior to the tumor.* ***(Right)*** *Transverse ultrasound of the same lesion shows a heterogeneous synovial mass arising from the glenohumeral joint. The biopsy pathway is planned to avoid the axillary neurovascular bundle.*

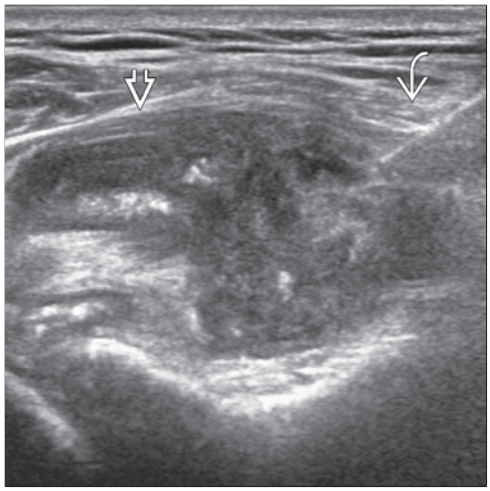
BIOPSY SOFT TISSUE TUMOR

(Left) Clinical photo shows the same patient after skin sterilization and application of sterile drapes. Local anesthetic (lignocaine 1% 3 mL) is infiltrated via a 23-g needle to the skin and subcutaneous tissue. (Right) Transverse ultrasound of the same patient shows the 23-g needle for injection of local anesthetic reaching the outer margin of the soft tissue tumor. The pseudocapsule around the tumor can be anesthetized, but the anesthetic needle should not enter the tumor.

Ultrasound-Guided Biopsy of Soft Tissue Tumor



Ultrasound-Guided Biopsy of Soft Tissue Tumor



(Left) Clinical photo shows the same patient after local anesthetic (LA) infiltration. A small skin incision is made at the site of the LA injection. (Right) Clinical photo shows the same patient under ultrasound guidance with a coaxial needle introduced via the small skin incision to the soft tissue tumor.

Ultrasound-Guided Biopsy of Soft Tissue Tumor

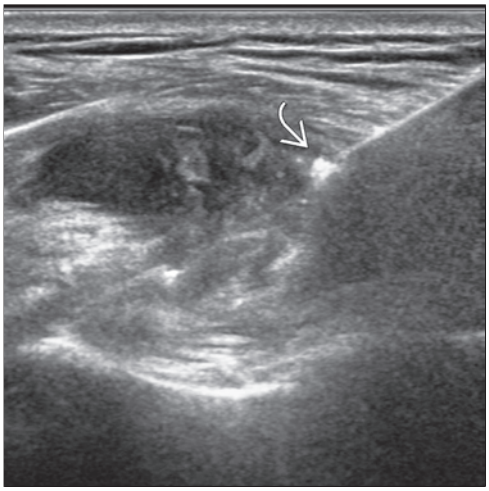


Ultrasound-Guided Biopsy of Soft Tissue Tumor



(Left) Transverse ultrasound of same patient shows the echogenic tip of the coaxial needle just piercing the tumor capsule. The tip of the coaxial system should be left in the outer margin of the tumor to optimize subsequent maneuverability. (Right) Clinical photo shows the same patient after removal of the inner stylet of the coaxial needle. The Tru-Cut biopsy needle is introduced and locked into the outer cannula of the coaxial needle.

Ultrasound-Guided Biopsy of Soft Tissue Tumor

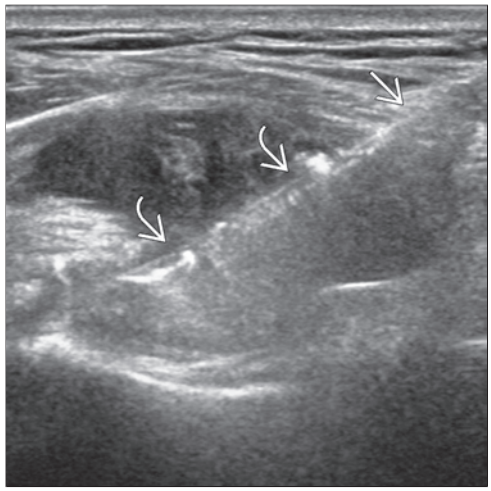


Ultrasound-Guided Biopsy of Soft Tissue Tumor



BIOPSY SOFT TISSUE TUMOR

Ultrasound-Guided Biopsy of Soft Tissue Tumor

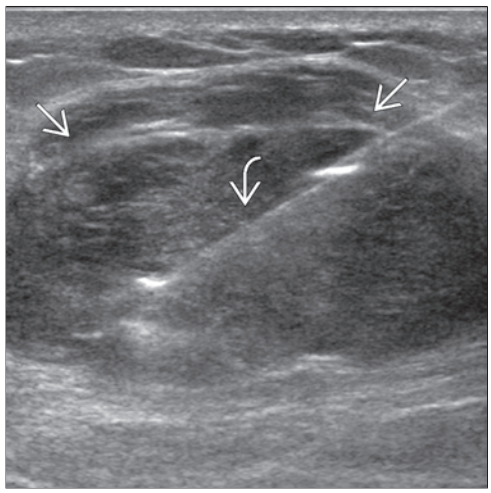


Ultrasound-Guided Biopsy of Soft Tissue Tumor

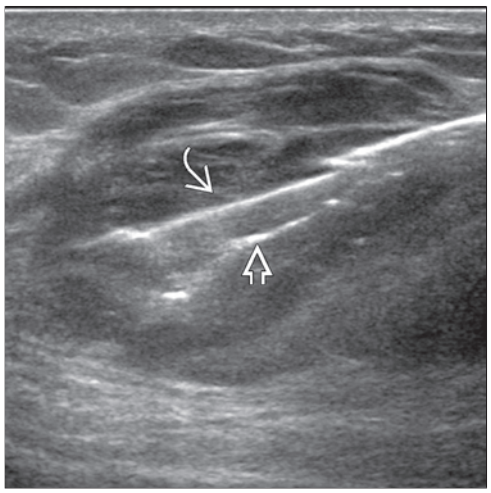


(Left) *Transverse ultrasound of the same patient shows advancement of the inner stylet beyond the coaxial needle, exposing the specimen slot of the Tru-Cut needle. Biopsy is performed with further pushing of the plunger of the Tru-Cut biopsy needle.* ***(Right)*** *Clinical photo shows a tissue core within the specimen slot of the Tru-Cut biopsy needle. The specimen is removed from the needle by "washing" it in normal saline. Histology and microbiology revealed tuberculous infection.*

Ultrasound-Guided Biopsy of Soft Tissue Tumor

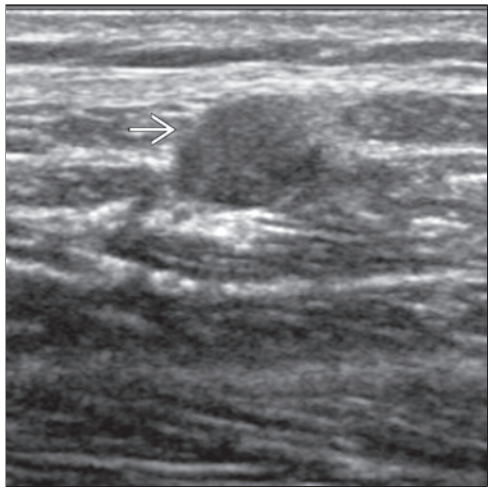


Ultrasound-Guided Biopsy of Soft Tissue Tumor

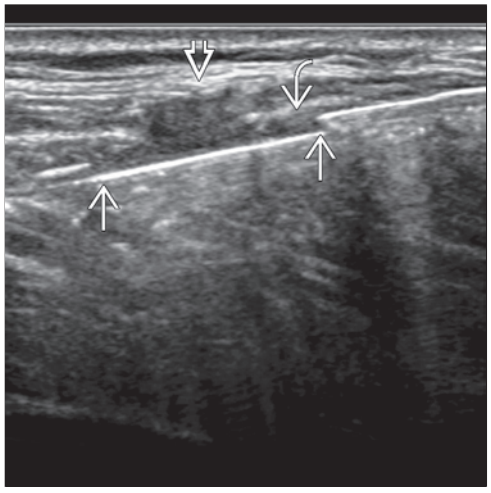


(Left) *Transverse ultrasound shows a Tru-Cut biopsy needle inserted into a soft tissue mass in the calf. Histology revealed a malignant fibrous histiocytoma. Note the advancement of the inner stylet of the Tru-Cut biopsy needle.* ***(Right)*** *Transverse ultrasound shows the Tru-Cut biopsy needle targeting the more superior portion of the tumor. The gas-filled tract from a previous biopsy is evident. In general, 3-4 good cores are adequate for histological analysis.*

Ultrasound-Guided Biopsy of Soft Tissue Tumor

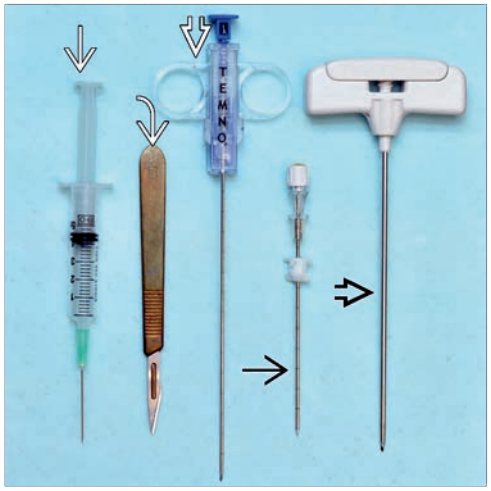


Ultrasound-Guided Biopsy of Soft Tissue Tumor



(Left) *Transverse ultrasound shows a small (11 mm) hypoechoic tumor within the soleus muscle in a patient with previous history of sarcoma. The ultrasound appearances are nonspecific.* ***(Right)*** *Transverse ultrasound shows that the specimen slot is positioned to include the small tumor as well as the adjacent normal tissue. When biopsy of small lesions is required, it is usually necessary to include normal tissue on either side of the mass, though extra care should be taken to avoid damage to vital structures.*

BIOPSY BONE TUMOR



Setup for US-guided bone biopsy shows local anesthetic ➔, scalpel ➔, Tru-Cut biopsy ➔, coaxial ➔, & trephine biopsy ➔ needles. Tumor extent and cortical integrity determine type of needle used.



Lateral radiograph shows very thinned, expanded cortex ➔ of a giant cell tumor of the distal radius, which would be suitable for ultrasound-guided bone biopsy.

TERMINOLOGY

Definitions

- Percutaneous biopsy of tumor originating in bone

PRE-PROCEDURE

Indications

- Indeterminate or malignant bone lesion, which is either surface based, has extended through the cortex, or has thin intact overlying cortex is amenable to ultrasound-guided biopsy
- ~ 40% of bone tumors referred to a specialist bone tumor unit are amenable to ultrasound-guided percutaneous biopsy
- Biopsy is best performed in center where definitive management of patient will take place
- Ultrasound-guided needle biopsy of bone tumors has diagnostic accuracy of > 98%
- Main advantages of ultrasound-guided biopsy over CT-guided biopsy
  - Continuous real-time visualization of biopsy needle relative to neurovascular structures is possible
  - Areas of viable tissue can be identified & accurately targeted
  - More expeditious & cost effective, particularly if multiple biopsies are obtained
  - Does not occupy high-end CT technology
  - Does not involve ionizing radiation

Contraindications

- Bone tumor inaccessible to ultrasound

Pre-Procedure Imaging

- Radiographs
  - Best at bone tumor characterization
- CT
  - Adequate for assessing metastatic tumor, plasmacytoma, or lymphoma
  - Not suitable for staging primary bone sarcoma or myeloma
- MR helps identify suitability for ultrasound-guided biopsy
  - Ideally, MR should be performed prior to ultrasound-guided biopsy
  - If there is scheduling difficulty, ultrasound-guided biopsy can be done prior to MR in tumors with large extraosseous mass
  - Effect of percutaneous biopsy on MR imaging characteristics is minimal
  - Adage that MR should be done before biopsy is a carryover from open biopsies where negative effect on MR imaging was significant
- Broadly, 3 bone tumor types are suitable for standard US-guided biopsy depending on preprocedure imaging
  - Bone tumor with extraosseous mass
  - Lytic bone tumor with breached cortex without extraosseous mass
  - Lytic bone tumor with intact thinned cortex
- Ultrasound fusion-guided biopsy greatly expands range of bone tumors amenable to US-guided biopsy

Getting Started

- Things to check
  - Check clotting profile
  - Time-out procedure (check patient name, location of bone tumor)
  - Discuss risk of infection, allergy, & bleeding
  - Obtain informed signed consent
  - Sedation rarely required
- Medications
  - It is advisable but not absolutely necessary to stop antiplatelet therapy, or even anticoagulation, prior to biopsy
    - Bleeding is rarely a problem, as adequate tamponade of biopsy site is feasible with most musculoskeletal biopsies
    - Bleeding is a much greater concern where adequate tamponade is not achievable, e.g., biopsy of inner aspect of iliac bone or deeper areas of spine
      - In these areas, must ensure normal coagulation profile & use smallest needle possible
  - Sedation or systemic analgesia usually not required

BIOPSY BONE TUMOR

Key Facts

Pre-Procedure

- ~ 40% of bone tumors referred to a specialist bone tumor unit are amenable to ultrasound-guided percutaneous biopsy
- Ultrasound-guided needle biopsy of bone tumors has diagnostic accuracy of > 98%

Procedure

- Choose biopsy site bearing in mind site of subsequent surgical excision
  - Can be performed as outpatient procedure
- Plan approach taking care to avoid any neurovascular bundle or other critical structures
- 3 potential scenarios
  - Extraosseous tumor or no bone cortex overlying lytic tumor: Coaxial needle & Tru-Cut needle technique is used
  - Thin bone cortex overlying lytic tumor: Coaxial needle used to penetrate cortex prior to insertion of Tru-Cut biopsy needle
  - Thinned but intact bone cortex overlying lytic tumor: Trephine biopsy needle used to penetrate cortex prior to insertion of Tru-Cut biopsy needle
- Color Doppler helps identify areas of viable tumor
- Biopsy edge of tumor if tumor is necrotic
- **Ultrasound fusion-guided biopsy**
  - Fuses previously obtained DICOM CT or MR data with real-time ultrasound
  - Expands applicability of percutaneous ultrasound-guided biopsy to bone lesions not visible on ultrasound
  - Provides diagnostic yield & accuracy of ~ 95%

    - Systemic analgesia, on the other hand, is usually used for CT-guided biopsies, which tend to be more painful due to deep-seated location of bone tumor
    - Ultrasound-guided biopsy of pathological fracture, particularly if only small extraosseous component, is often more painful & may require systemic analgesia

PROCEDURE

Patient Position/Location

· Choose biopsy site bearing in mind site of subsequent surgical excision
  - Helpful if orthopedic surgeon can mark planned surgery site on skin
    - Allows biopsy tract to be excised at time of surgery
· Biopsy can be performed as outpatient procedure
  - Even young patients (i.e., > 7 years) can undergo percutaneous biopsy under local anesthetic
  - Most very young patients (i.e., < 7 years) will require general anesthesia
  - Do not physically restrain patient to do biopsy
    - Instead, rearrange alternative date for biopsy under general anesthesia
· Perform preliminary ultrasound to ensure that tumor is suitable for ultrasound-guided needle biopsy & plan best approach to tumor before cleansing skin
· Plan approach, taking care to avoid any neurovascular bundle or other critical structures (e.g., spermatic cord)
  - Use color Doppler imaging to identify hypervascular areas within tumor
  - Hypervascular regions invariably contain viable tumor
  - Identify cystic or hemorrhagic areas within tumor, which should be avoided for biopsy
  - If all of visible tumor is hypovascular, biopsy of tumor margin will increase likelihood of obtaining diagnostic sample
· Patient is placed in either decubitus, supine, or prone position that will allow best access to planned biopsy path
  - Ensure that patient is comfortable in that position
  - Remember that repositioning patient with pathological fracture is difficult
    - In patient with pathological fracture, try, whenever possible, to perform biopsy without removing external fixation (backslab) device
· Use your dominant hand to guide biopsy needle whenever possible
· 3 possible ultrasound-guided techniques can be considered, depending on integrity of bone cortex
  - Extraosseous tumor or no bone cortex overlying lytic tumor: Coaxial needle & Tru-Cut needle technique is used
  - Very thin bone cortex overlying lytic tumor: Standard coaxial needle used to penetrate very thin cortex, then biopsy tumor with Tru-Cut needle inserted via this coaxial needle
  - Thinned (but not very thinned) intact bone cortex overlying lytic tumor: Penetrate cortex using trephine needle
    - Trephine needle stilette is then removed & 16-g Tru-Cut needle passed through trephine cannula into lytic bone tumor
· Check that Tru-Cut biopsy needle is sufficiently long to acquire biopsy once opened within coaxial needle or trephine needle
  - Normally, 15 cm 16-g Tru-Cut needle is used in conjunction with 10 cm 15-g coaxial or 11-g trephine needle

Equipment Preparation

· Sterile trolley & drapes
· Sterile gloves ± gown or eye protector
· Antiseptic cleansing solution
· Protective sheath for ultrasound transducer
· Sterile ultrasound gel
· Lignocaine 1% local anesthetic 3-4 mL
· 15-g coaxial needle
· 16-g Tru-Cut biopsy needle

Procedure Steps

· Cleanse & drape skin
· Lignocaine 1% local anesthetic to skin & (if cortex intact) periosteum
· Small stab incision in skin
· Free-hand technique is most commonly used
  - Can also attach a needle guide to transducer

BIOPSY BONE TUMOR

- Advance coaxial needle into closest margin of tumor under real-time imaging
  - Only advance needle when it is clearly visible on real-time imaging
  - Use a slow rotating/pushing action of coaxial needle rather than a pure pushing action to penetrate investing fascia & pseudocapsule of tumor
  - Maintain finger contact with skin during this rotating pushing action to prevent needle from lunging forward
  - If cortex intact, can apply further anesthetic to periosteum prior to cortex penetration
- Try to keep coaxial needle tip within confines of tumor
  - Maintain control of needle tip
  - Ask assistant to hold coaxial needle if necessary
- Position coaxial needle tip in outer periphery of tumor
  - Maximizes dexterity when angling coaxial needle to biopsy different parts of tumor
- Remove inner stylet of coaxial needle & replace with biopsy needle
- Open biopsy needle & take biopsy only under real-time imaging
- Avoid cystic & necrotic areas, aiming to target the most viable tumor tissue for biopsy
  - Biopsy edge of tumor if tumor necrotic
- Sampling different parts of tumor ensures a representative biopsy sample
- Number of biopsies taken depends on friability of tumor
  - If tumor is not friable, 3 biopsies from different parts of tumor is adequate
  - If tumor is friable, may need to take > 10 biopsies from different parts of tumor, particularly tumor margins
- Apply direct pressure to biopsy site for 5 minutes after procedure or longer (15 minutes) if tumor hypervascular
- Apply simple dressing & observe within department for 1 hour after biopsy
- If no signs of bleeding at 1 hour (swelling, bruising, oozing from wound), patient is discharged & can remove dressing after 1 day

Alternative Procedures/Therapies

- **Ultrasound fusion-guided biopsy**
  - Fuses previously obtained DICOM CT or MR data with real-time ultrasound
  - Uses navigation system that allows accurate determination of transducer position
- Ultrasound fusion-guided biopsy is well suited to percutaneous biopsy of bone lesions
  - Expands applicability in enabling percutaneous ultrasound-guided biopsy of bone lesions not visible on ultrasound
  - Provides overall diagnostic yield (adequacy of biopsy specimen) of 94% & diagnostic accuracy (of specimen relative to final diagnosis) of 95%
- CT or MR DICOM data loaded onto ultrasound system
  - 2 electromagnetic sensors clipped onto bracket placed over ultrasound transducer
  - Radiofrequency transmitter connects transducer sensors to ultrasound system
  - Ultrasound transducer placed in same imaging plane as uploaded CT or MR data
  - 1 or more anatomical landmarks identified on both ultrasound and CT/MR
  - Embedded software then fuses ultrasound and CT/MR images
  - Areas corresponding to those seen on ultrasound can be seen on CT or MR
  - Both ultrasound and CT/MR data can be viewed side-by-side or as an image overlay where ultrasound image overlaps CT or MR image

OUTCOMES

Complications

- Most feared complication(s)
  - Neurovascular injury can be avoided by
    - Carefully identifying all nerves & vascular structures within needle path
    - Remembering that large tumors may efface or displace neurovascular bundles, so must trace proximally or distally from tumor to identify any neurovascular bundle
    - Checking on anatomy section if you are unsure as to presence & location of nerve or vessels in vicinity of tumor
    - Only advancing biopsy needle under real-time imaging
    - Trying not to allow biopsy needle to pass into normal tissues beyond tumor, particularly if not well seen
- Immediate/periprocedural complication(s)
  - Bent Tru-Cut needle due to forcefully opening biopsy needle against bone
    - Can be avoided by not forcefully opening biopsy needle & planning biopsy tract to avoid any residual tumoral bone
    - Biopsy needle should open freely without pressure
    - If resistance encountered, alter needle direction & continue opening biopsy needle within tumor
    - Alternatively, unlock coaxial Luer lock & allow biopsy needle to slide backward during biopsy
  - Pain is usually minor &, at most, requires mild analgesia for 24 hours
  - Slight bruising at injection site
- Delayed complication(s)
  - Infection & delayed hemorrhage
    - Both complications are interrelated & very rare
  - Properly performed percutaneous bone biopsy is a safe procedure with few complications

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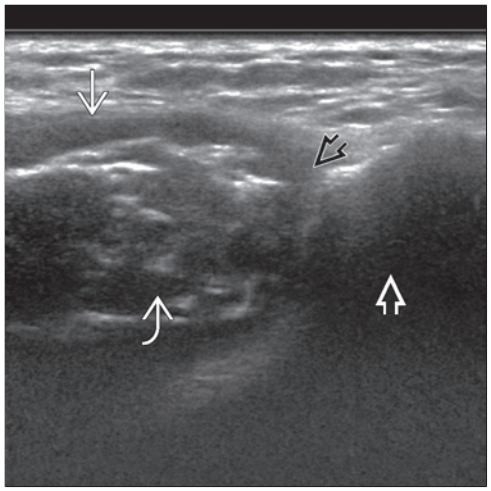
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BIOPSY BONE TUMOR

Metastatic Bone Tumor

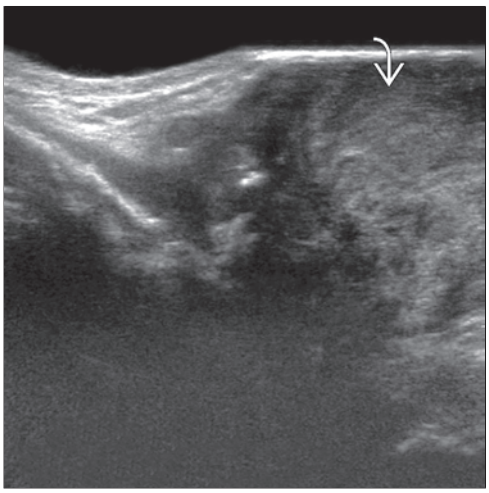


Metastatic Bone Tumor

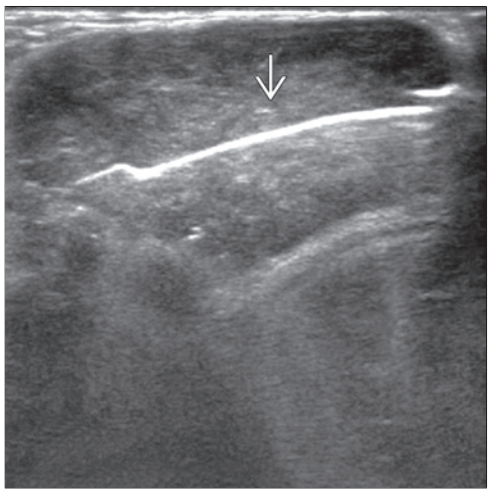


(Left) *Patient with left mastectomy for breast carcinoma 2 years previously shows recent onset of increasing upper chest wall mass. **(Right)** Transverse ultrasound in the same patient shows infiltrative tumor with resorption at the medial end of the left clavicle, abutting the manubrium. There is a thin, hypoechoic, extraosseous tumor rim. The manubrium is normal as is the sternomanubrial junction. In this clinical context, this is highly suspicious of metastatic tumor.*

Metastatic Bone Tumor

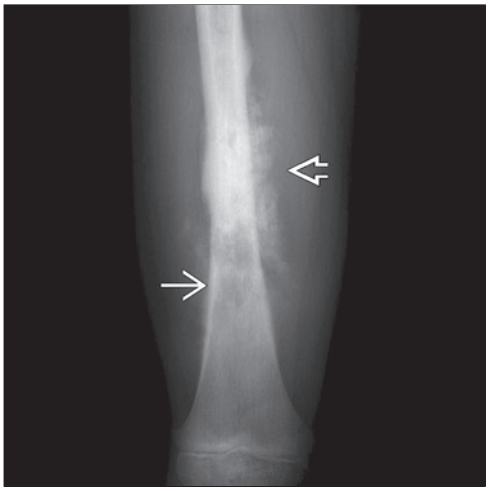


Metastatic Bone Tumor



(Left) *Transverse ultrasound of the same patient shows a large, extraosseous sternal mass with complete cortical resorption. This area of the tumor is much more suitable for ultrasound-guided biopsy than the medial clavicle. **(Right)** Transverse ultrasound shows the same sternal tumor during ultrasound-guided biopsy. In chest wall lesions, try to use a horizontal rather than a vertical biopsy approach whenever possible to minimize risk to intrathoracic structures. Histology revealed metastatic breast carcinoma.*

Primary Bone Tumor



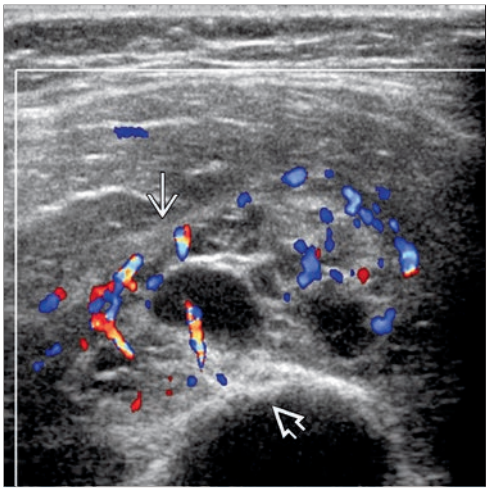
Primary Bone Tumor



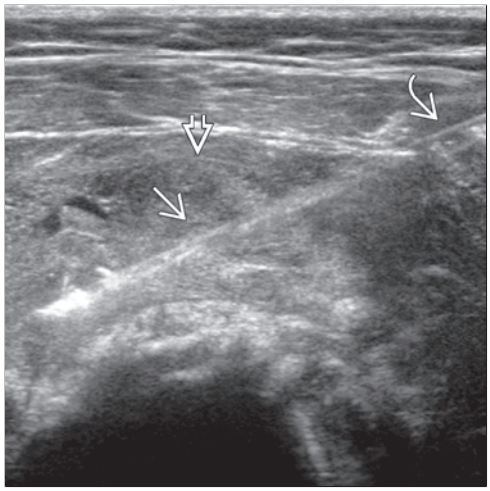
(Left) *Frontal radiograph in a skeletally immature patient shows severe infiltrative-like osteolysis with extensive tumoral new bone formation in the midfemoral diaphysis with soft tissue swelling. **(Right)** Coronal T1WI C+ MR of the same patient more clearly shows the extraosseous tumor extent & a greater degree of intramedullary tumor extent than seen radiographically. MR imaging is usually advisable prior to any ultrasound-guided bone tumor biopsy.*

BIOPSY BONE TUMOR

Primary Bone Tumor



Primary Bone Tumor

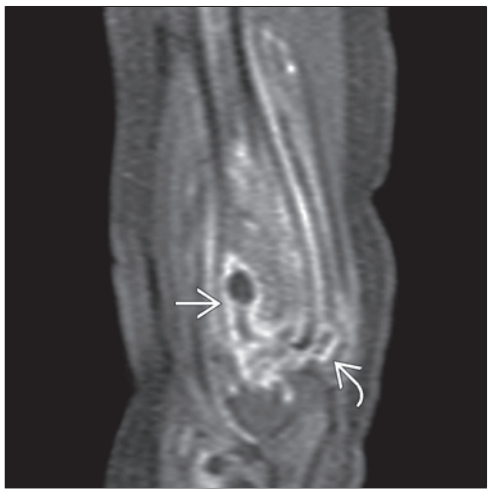


(Left) *Transverse color Doppler ultrasound in the same patient as previous image shows a moderately hypervascular ➔, mixed solid/cystic extraosseous tumor infiltrate. The underlying femoral cortex ➔ is largely intact.* ***(Right)*** *Transverse ultrasound during ultrasound-guided biopsy shows how the more solid component of the extraosseous tumor ➔ has been selected for biopsy. The 16-g Tru-Cut needle ➔ has been inserted through a 15-g coaxial needle ➔. Histology revealed osteosarcoma.*

Chronic Osteomyelitis

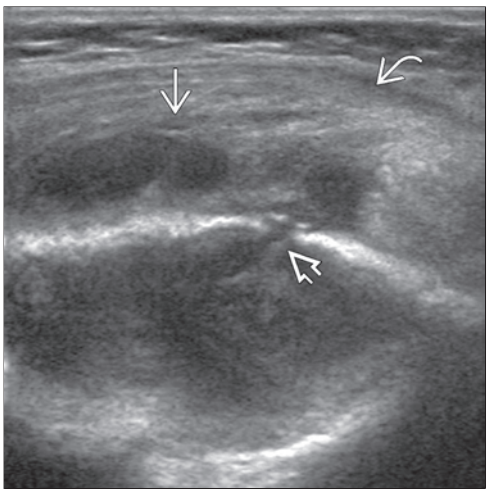


Chronic Osteomyelitis

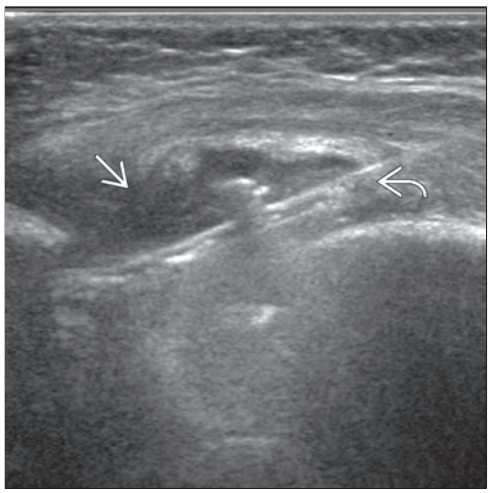


(Left) *Lateral radiograph of the distal humerus in a young patient with clinically suspected infection shows quite marked expansion of distal humerus, medullary osteolysis ➔, mature-type periosteal new bone formation ➔, and moderate soft tissue swelling consistent with chronic osteomyelitis.* ***(Right)*** *Sagittal fat-suppressed T1WI C+ in the same patient shows a medullary sinus tract and abscess ➔ extending to the dorsum of the distal humerus ➔, consistent with acute exacerbation of chronic osteomyelitis.*

Chronic Osteomyelitis



Chronic Osteomyelitis

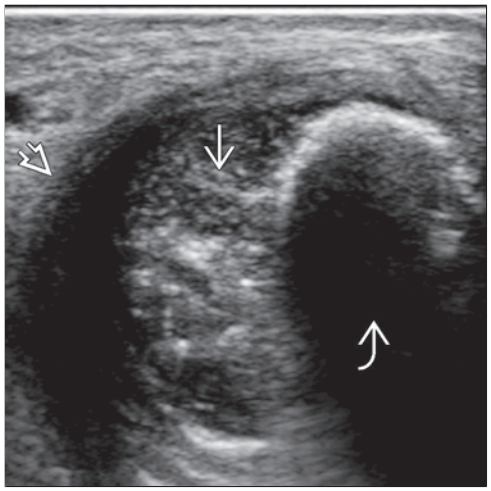


(Left) *Transverse ultrasound in the same patient shows thinning & breaching of the distal humeral cortex ➔ with focal juxtacortical edematous inflammatory tissue ➔ deep to an edematous triceps muscle ➔.* ***(Right)*** *Transverse ultrasound shows the same area during ultrasound-guided biopsy of the juxtacortical inflammatory tissue ➔ using a coaxial technique with a 16-g Tru-Cut biopsy needle ➔. Culture of this biopsy material grew Staphylococcus aureus.*

Chronic Osteomyelitis

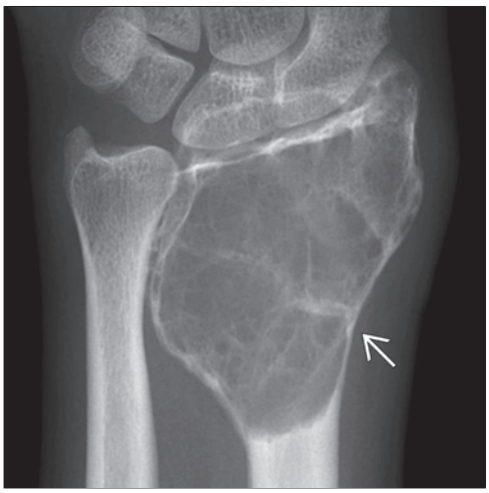


Chronic Osteomyelitis

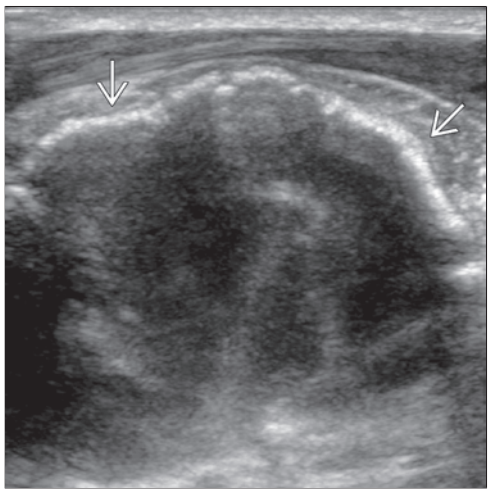


(Left) *Frontal radiograph of a 14 year old with fever & wrist pain shows a lytic lesion with a wide zone of transition in the distal ulnar metaphysis* ➔. ***(Right)*** *Transverse ultrasound of the same patient shows a prominent solid-appearing, juxtacortical soft tissue mass surrounding the distal ulna* ➔ *with echogenic seams of new bone formation* ➔. *An outer hypoechoic area representing fluid or severe edema is present* ➔. *Ultrasound-guided biopsy revealed chronic osteomyelitis.*

Primary Bone Tumor

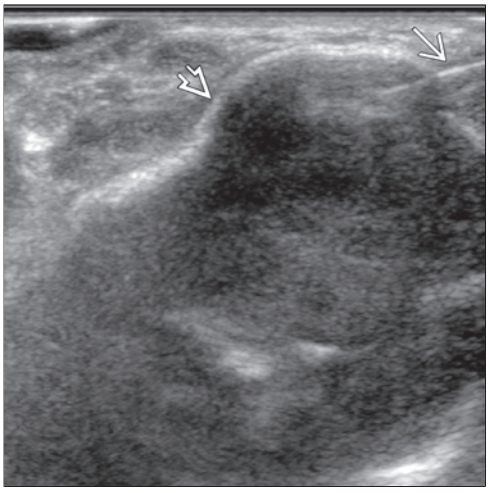


Primary Bone Tumor

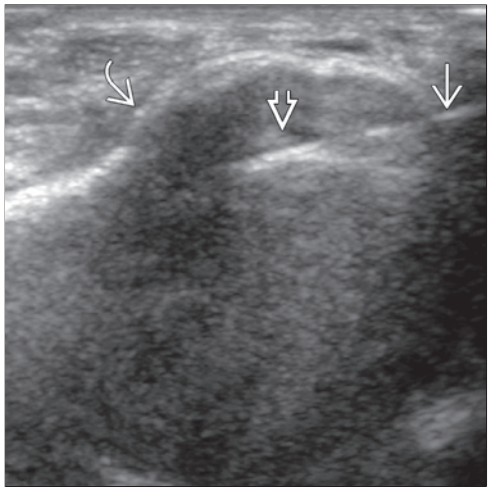


(Left) *Frontal radiograph shows a well-defined, expanded subarticular osteolytic lesion* ➔ *with a "soap bubble" appearance in the distal radius, consistent with a giant cell tumor. The cortex is intact though very thinned.* ***(Right)*** *Transverse ultrasound of the same patient shows an expanded intact cortex* ➔ *of the distal radius. One must rely on additional imaging such as radiography to appreciate that the cortex is thinned and that the tumor is osteolytic. Although the cortex is intact, the tumor is still amenable to US-guided biopsy.*

Primary Bone Tumor



Primary Bone Tumor



(Left) *Transverse ultrasound of the same tumor shows a 15-g coaxial needle* ➔ *just after piercing the thin cortical shell* ➔ *of the distal radial tumor. Gentle sustained pressure/rotation on the coaxial needle allows penetration of the cortex.* ***(Right)*** *Transverse ultrasound of the same tumor shows a 16-g Tru-Cut needle* ➔ *inserted through 15-g coaxial needle* ➔ *to biopsy the distal radial tumor* ➔. *Several biopsies from different parts of the tumor revealed giant cell tumor of bone.*

BIOPSY BONE TUMOR

(Left) *Clinical photograph of a 19-year-old man shows a swelling ⇨ on the medial aspect of the forefoot which had been slowly growing for 3 months.* ***(Right)*** *Frontal radiograph of the same patient shows a markedly expanded osteolytic tumor with thinned though seemingly intact overlying cortex ➔ at the proximal end of the 1st metacarpal bone. Although there is no extraosseous soft tissue component, this tumor is suitable for ultrasound-guided biopsy.*

Primary Bone Tumor

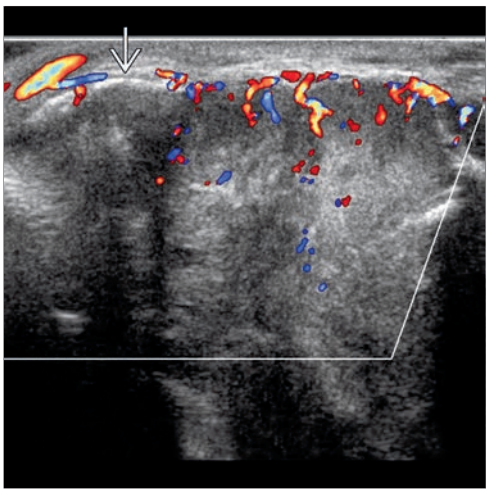


Primary Bone Tumor



(Left) *Transverse color Doppler ultrasound of the same patient shows an osteolytic tumor of the 1st metacarpal bone. The extremely thinned cortex is barely visible on ultrasound ➔. This thinned cortex causes so little beam attenuation that the tumor & its vascularity can still be readily appreciated.* ***(Right)*** *Transverse ultrasound of the same patient during bone biopsy shows a 15-g coaxial needle ➔ just after piercing the thin cortex ➔ overlying the tumor.*

Primary Bone Tumor

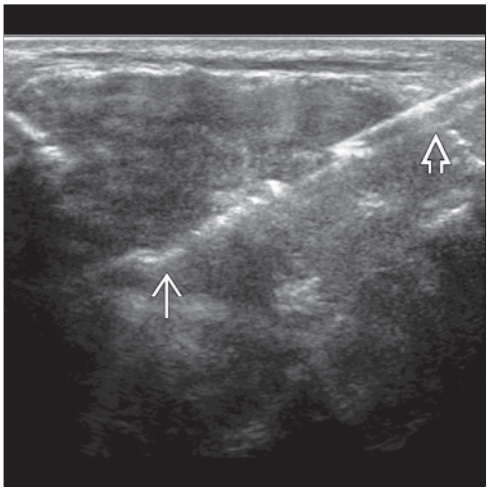


Primary Bone Tumor

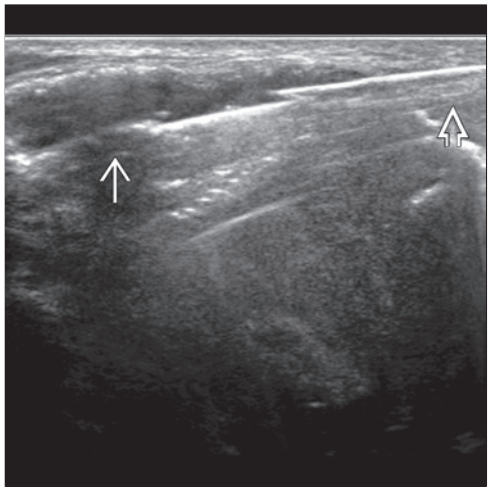


(Left) *Transverse ultrasound of the same patient shows a 16-g Tru-Cut needle ➔ inserted though the 15-g coaxial needle ➔ to biopsy the central part of metacarpal bone tumor.* ***(Right)*** *Transverse ultrasound of the same tumor shows the 16-g Tru-Cut ➔ & coaxial needle ➔ repositioned to biopsy a more superficial part of the metacarpal bone tumor. At least 3 biopsies from different parts of the tumor should be obtained. Histology revealed a giant cell tumor.*

Primary Bone Tumor



Primary Bone Tumor

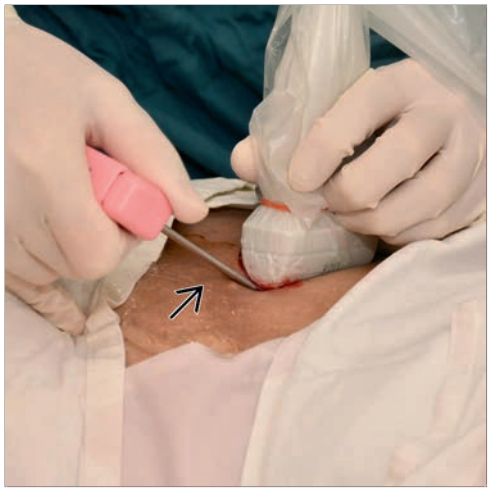


BIOPSY BONE TUMOR

Primary Bone Tumor

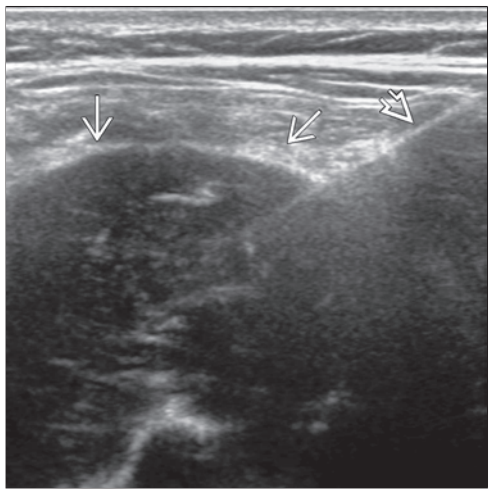


Primary Bone Tumor

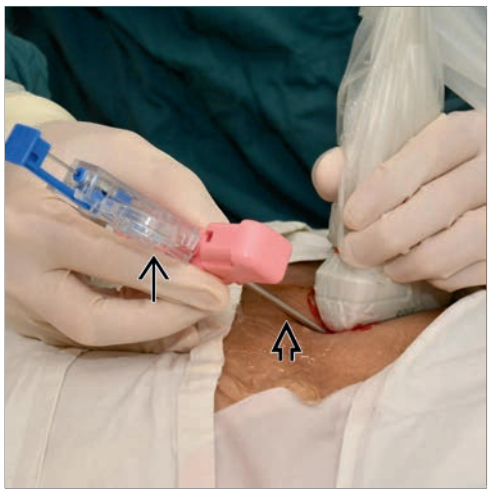


(Left) *Clinical photograph shows local anesthetic infiltration ⇒ at the site chosen for percutaneous biopsy of sacral tumor. The dermal and periosteal tissues should be preferentially infiltrated.* ***(Right)*** *Clinical photograph shows insertion of an 11-g trephine biopsy needle ⇒ following a short stab incision with a scalpel along the chosen biopsy path. Once the cortex of the tumor is penetrated, the inner stylet is removed from the outer cannulated trephine biopsy needle.*

Primary Bone Tumor



Primary Bone Tumor

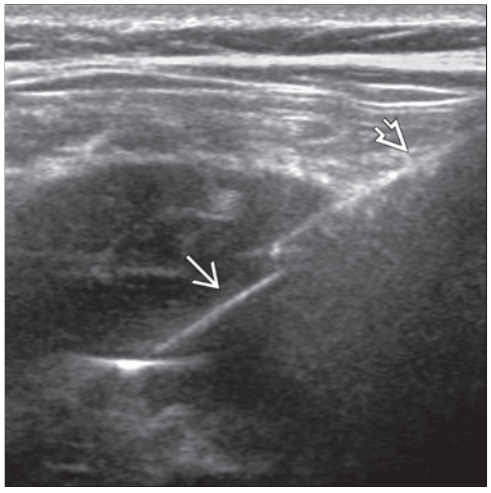


(Left) *Longitudinal ultrasound of the same patient shows the trephine needle ⇒ piercing the thinned expanded cortex ⇒ of the sacral tumor. A Tru-Cut needle alone would usually not be able to pierce an intact thinned bone cortex.* ***(Right)*** *Clinical photograph shows a 15-g Tru-Cut needle ⇒ introduced into the tumor via the cannula of the trephine biopsy needle ⇒ following removal of the outer stylet.*

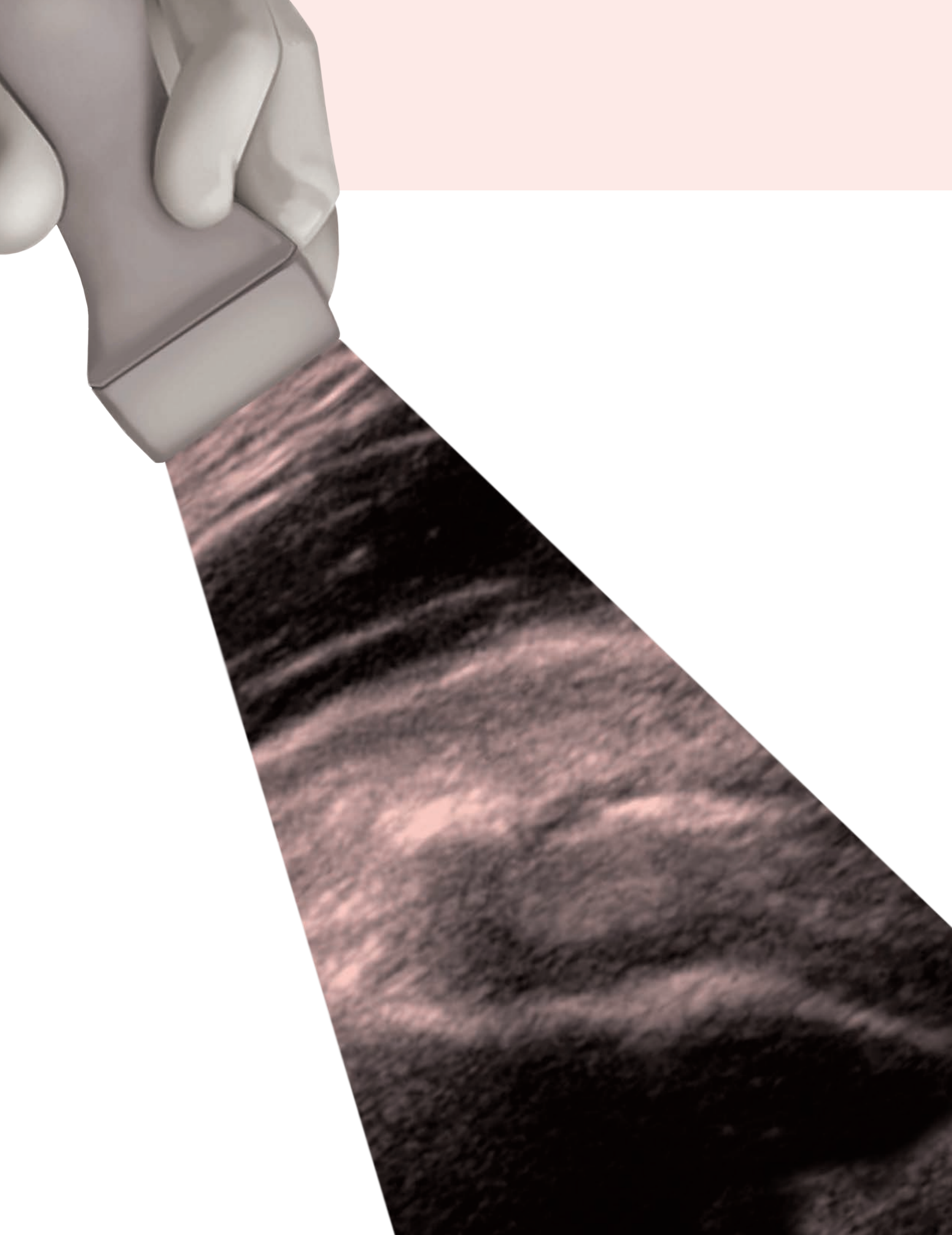
Primary Bone Tumor



Primary Bone Tumor



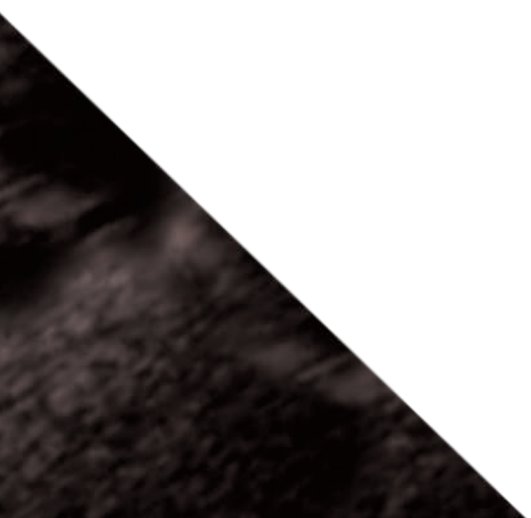
(Left) *Clinical photograph of the same patient during biopsy shows depression of the biopsy needle plunger ⇒ under real-time ultrasound guidance. An assistant is securing the position of the trephine needle ⇒ at this stage.* ***(Right)*** *Longitudinal ultrasound of the same patient shows specimen slot of the Tru-Cut needle ⇒ extending beyond the tip of the trephine biopsy needle ⇒. All needle advancement is performed under real-time ultrasound guidance. Histology revealed a chordoma.*



SECTION 2

Joint Procedures

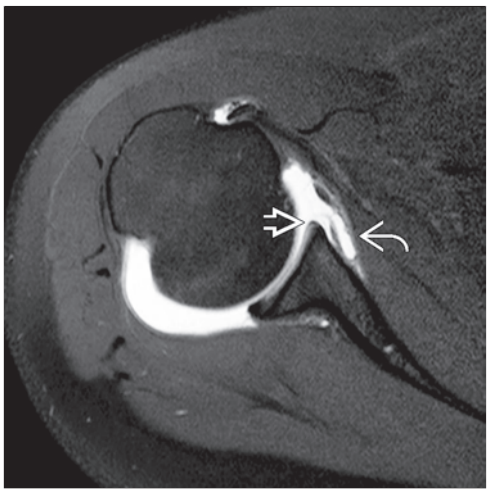
Shoulder Procedures **IV**-2-2
Elbow Procedures **IV**-2-10
Hand and Wrist Procedures **IV**-2-16
Hip and Pelvis Procedures **IV**-2-22
Knee Procedures **IV**-2-30
Ankle and Foot Procedures **IV**-2-38



SHOULDER PROCEDURES



Clinical photo shows needle (22-g spinal) ➔ position for posterior approach to glenohumeral joint for contrast injection before MR arthrography in a patient with shoulder dislocation.



Axial MR arthrogram T1WI FS (same patient) shows glenohumeral joint distension. Note anterior capsular stripping ➔ and labral avulsion ➔. US-guided MR arthrography is a commonly performed procedure.

PRE-PROCEDURE

Indications

- **Glenohumeral joint injection or aspiration**
  - MR, CT, or conventional arthrography
  - Medication for control of inflammation or pain relief such as in adhesive capsulitis
  - Diagnosis of septic arthritis or crystal arthropathy
- **Subacromial-subdeltoid (SA-SD) bursa injection**
  - For control of inflammation and symptom relief
- **Calcific tendinitis therapy**
  - For control of inflammation, symptom relief, and to promote resorption of calcific deposits
    - Only painful calcific tendinitis should be treated
- **Rotator cuff tendinosis or partial tear therapy**
  - For control of symptoms and to promote tissue repair
- **Acromioclavicular (AC) joint injection**
  - For control of inflammation and symptom relief

Contraindications

- Infection of overlying soft tissues
- Uncorrected bleeding diathesis

Getting Started

- Things to check
  - Time-out procedure (check identity of patient, type and side of procedure)
  - Signed informed consent
    - Specifically warn patient regarding risk of calcific bursitis after calcific tendinitis therapy, which can be very painful
  - Discuss risk of infection, allergy, and bleeding
  - Sedation is rarely required
- Medications
  - Short-acting local anesthetic (LA) (1-3 mL 1% lignocaine) for skin
  - Short- or long-acting anesthetic for intraarticular injection
    - 1-2% lignocaine or 0.25-0.5% bupivacaine (Marcaine)
  - Steroid
    - Short (hydrocortisone) or long acting (dexamethasone, methylprednisolone)
  - Contrast
    - CT arthrography: Iodinated contrast, e.g., Omnipaque 300 ± 0.1 mL of 1:1,000 epinephrine
    - MR arthrography: Diluted gadolinium 0.1 mL gadolinium in 10 mL normal saline solution
- Equipment list
  - Sterile set
  - Spinal needles
    - 20- to 22-g for injection, 18- to 22-g for aspiration
    - Size varies according to consistency of fluid injected or aspirated
    - Thinner needle used in patients with bleeding diathesis
  - Extension tube (thin, 250 mm long, 8.5 Fr, 0.4 mL dead space)
  - 3-way connector
  - Syringes for LA, aspiration, and injection
  - Sterile specimen bottles

PROCEDURE

Procedure Steps

- General preparation of all percutaneous intervention
  - Sterile technique (operator, probe, patient)
    - LA to skin at puncture site
      - For some quick straightforward procedures (e.g., joint injection), anesthesia optional
- **Glenohumeral joint injection or aspiration**
  - General practical points irrespective of anterior (rotator cuff interval) or posterior approach
    - Use free-hand technique to advance needle into joint space under real-time imaging
      - 20- to 22-g spinal needle for injection
      - 18- to 22-g spinal needle for aspiration
    - Can use long-axis or short-axis approaches
    - Ensure on real-time imaging that needle tip is within joint space
      - Aspirate joint fluid prior to injection if moderate to large effusion present

SHOULDER PROCEDURES

Key Facts

Pre-Procedure

- Indication
  - Glenohumeral joint aspiration (suspected infection) or injection (contrast for arthrography; adhesive capsulitis symptom relief)
  - Subacromial-subdeltoid (SA-SD) bursal injection (symptom relief) or aspiration (suspected infection)
  - Calcific tendinitis (symptom relief)
  - Rotator cuff tendinosis or tear (symptom relief & to promote healing)

Procedure

- Glenohumeral joint aspiration or injection
  - Anterior (rotator cuff interval) or posterior approaches
  - 21- to 23-g needle for aspiration, 18- to 22-g needle for injection
- SA-SD bursal injection or aspiration
  - Lateral, anterior, & superior approaches
  - Steroid & long-acting local anesthetic to SA-SD bursa
- Calcific tendinitis
  - Percutaneous lavage & aspiration of calcific deposits
  - Single or double-needle techniques
  - Steroid & long-acting LA injected to bursa
- Rotator cuff tendinosis or tear
  - Steroid & LA injection to SA-SD bursa (to reduce inflammation)
  - Localized dry needling of tendinosis or tear (to promote healing)
  - Platelet-rich plasma injection of rotator cuff partial tear (to promote healing)

    - Avoid injection of bubbles by first flushing syringe and tubing with injectate
    - Free flow of fluid with low pressure injection and minimal patient discomfort helps confirm intraarticular position of needle tip
    - Avoid active exercise to prevent leakage of solution along needle track for 20 minutes
  - Posterior approach
    - Various positions can be used
      - Lateral decubitus position with arm mildly adducted
      - Prone position with arm in external rotation, palm facing down, and shoulder resting on pillow
      - Sitting position with back toward you, ipsilateral hand resting on contralateral shoulder (be alert for vasovagal syncope)
    - Scan in longitudinal plane to identify posterior glenohumeral joint, glenoid, labrum, and humeral head deep to infraspinatus musculotendinous junction
      - Slight passive rotation of arm while scanning will help identify glenohumeral joint
    - Either a short-axis (preferable) or long-axis needle approach can be used
    - Short-axis approach allows joint to be approached more vertically than with long-axis approach
      - Needle entry point is immediately superficial to glenohumeral joint
      - Needle is advanced almost vertically under real-time imaging until tip is seen to enter glenohumeral joint
    - "Pop" felt when needle transverse joint capsule
  - Rotator interval approach
    - Patient in a supine position with arm partially externally rotated
      - Avoid extreme external rotation as it increases tension on anterior shoulder and increases risk of extraarticular leakage
    - Identify coracoid process and adjacent superomedial aspect of humeral head with probe aligned transverse to joint line
    - Needle entry point is just superior to subscapularis tendon and lateral to coracoid process
      - Needle is advanced until tip contacts articular cartilage of humeral head
- **Arthrography**
  - 10–20 mL of contrast solution is injected until joint capsule is satisfactorily distended
  - Volume of injection is determined according to patient's comfort level and resistance to injection
  - Patients with severe adhesive capsulitis will feel distension discomfort after only a small volume (5-10 mL) of fluid injected into joint
  - Patients following shoulder dislocation can accommodate larger volumes (15-20 mL)
- **Adhesive capsulitis treatment**
  - To reduce inflammation and relieve pain
    - 10 mL bupivacaine 0.25-0.5% mixed with 1-2 mL of 40 mg/mL methylprednisolone
    - Benefits of single injection of bupivacaine outweigh theoretical risk of chondrolysis
    - Other anesthetic agents (ropivacaine 0.5%) is less toxic to human articular chondrocytes in vitro
    - Sodium hyaluronate (sodium salt of hyaluronic acid) mixed with anesthetic is alternative if steroids contraindicated
    - Good symptom control after steroid injection, especially in those who have adhesive capsulitis with mainly inflammatory rather than fibrotic component
    - Inflammatory vs. fibrotic component can be assessed with MR prior to intraarticular injection of contrast
  - Hydrodilatation to achieve capsular rupture
    - Potentially more useful in those patients with more fibrotic rather than inflammatory component to adhesive capsulitis
    - Larger volume of saline mixed with 5 mL 0.25% or 0.5% bupivacaine and 1-2 mL of 40 mg/mL methylprednisolone/triamcinolone
      - Usually 30-40 mL saline mixture is required for optimal distension/capsular rupture
    - Capsular distension is better visualized under fluoroscopy
    - 5 mL of radiopaque contrast into saline mixture
- **Subacromial-subdeltoid bursa injection**

- Examine shoulder in different degrees of rotation with arm by side to optimize bursal fluid accumulation
- Approaches differ depending on quantity and location of bursal fluid
  - Lateral approach (most frequently used)
    - Probe positioned parallel to long axis of supraspinatus tendon
  - Anterior approach
    - Probe positioned on axial plane in front of shoulder with needle inserted in lateromedial direction
  - Superior approach
    - Used if fluid located in craniomedial aspect of subacromial-subdeltoid bursa between trapezius and upper surface of supraspinatus
    - Probe positioned in supraspinatus fossa along long axis of supraspinatus with lateral edge overhanging acromion
- Steroid injection
  - Point bevel of needle facing supraspinatus tendon such that needle will glance off surface of tendon and enter bursa
  - 1-2 mL of 40mg/mL methylprednisolone or triamcinolone mixed with 5 mL 0.25% or 0.5% bupivacaine
    - Injection observed in real time with hypoechoic fluid seen to disperse within bursa
    - If needle is appropriately positioned, injectate should flow freely away from needle
    - No injectate should be collected around needle tip
    - Rescan rotator cuff post injection to assess for small bursal surface tears, as injectate will tract into tears and make them more easily visible
- Good short-term symptom relief after steroid injection

Calcific tendinitis therapy

- Preliminary ultrasound examination to assess size and distribution of calcific deposits
- Only painful calcific tendinitis should be treated
- Calcifications best targeted
  - Largest calcification
  - Calcification producing most focal tendon edema
  - Calcification that most closely correlates with symptoms
- Position patient so that calcification to be treated is well seen and amenable to needle placement
  - Usually supine or lateral decubitus positions
- Single-needle or double-needle technique
  - 21- to 23-g needle for local anesthesia
  - 18- to 22-g needle for lavage and aspiration of calcium
  - Inject local anesthetic (3-5 mL, 1% lignocaine) into subcutaneous tissue, subacromial-subdeltoid bursa, and around tendon calcification
  - Avoid introducing air during infiltration of local anesthesia as this will obscure calcification
- Single-needle technique
  - Introduce lavage needle to center of calcium deposit
    - Needle is connected to syringe containing 5-10 mL sterile saline (70%) and lignocaine 1% (30%)
    - Undertake gentle rotational and "to and fro" movement to grind calcification, followed by injection and aspiration of saline solution
    - Fluid-filled hypoechoic cavity is seen within calcification, expanding when fluid is pushed forward, reducing when pressure is released
    - Calcium is dissolved and a cloudy whitish fluid will decompress into syringe when releasing plunger
    - Repeated short series of press and release gives best result
    - Syringe exchange is necessary to keep solution clear during procedure
    - Stop lavage when no more calcium can be retrieved
- Double-needle technique
  - 2 needles are inserted into calcification
  - Tips of these needles are very close to each other; not more than 2-3 mm apart
  - Both needles should be inserted along same coronal plane so that both needles and the calcification can be seen simultaneously
    - 1st needle is inserted slightly deeper than 2nd needle
    - Angulation between the 2 needles should be 25-30°
  - Bevels of needles face each other
    - Bevel of 1st needle faces upward
    - Bevel of 2nd needle faces downward
  - Undertake gentle rotational and "to and fro" movement to grind calcification
  - Inject 5-10 mL of sterile saline (70%) and 1% lignocaine (30%) into calcium via 1 of needles
  - Dissolved calcium content is drained from other (free) needle
  - Syringe exchange is necessary to keep solution clear during procedure
  - Stop lavage when no more calcium can be retrieved
- Reposition needle to subacromial-subdeltoid bursa after lavage in both techniques
  - Inject 1-2 mL of 40 mg/mL methylprednisolone or triamcinolone mixed with 5 mL 0.25% or 0.5% bupivacaine
    - This helps to treat and prevent crystal-induced bursitis, which can be very painful
- Clinical success rate varies from 60-75%

Rotator cuff tendinosis or partial tear therapy

- Reduce inflammation
  - Steroid (methylprednisolone 40 mg) and LA (5 mL 0.5% bupivacaine) injection to SA-SD bursa
- Promote healing
  - Localized dry needling of tendinosis or tear
    - 23-g intravenous needle repeatedly moved "to and fro" within tendinosis area
    - Converts area of quiescent tendinosis or tear into injured, functionally stable area
    - Resultant bleeding leads to deposition of blood cells (stem cells) within tendon or tendon tear
    - Reparative response leads to recruitment of reparative growth factors
  - Platelet-rich plasma (PRP) injection
    - Inject 5 mL platelet-rich plasma concentrate (extracted from patient's own venous blood)

- PRP is a source of circulating mesenchymal stem cells and reparative growth factors
- Injection to gap between tendon ends in partial or complete tears
- May improve clinical, mechanical, and histological outcome in rotator cuff tears
- Controversial result at 12-month follow-up
- Does not influence retear rate after full thickness rotator cuff repair

· **Acromioclavicular joint injection**
  ◦ For symptomatic relief in acromioclavicular joint arthropathy
  ◦ Patient in supine position
  ◦ Transducer placed onto skin over superior aspect of AC joint
    ▪ Transverse axis of AC joint
    ▪ Allows excellent visualization of needle tip throughout, and less likely to be restricted by large osteophytes
  ◦ Using a transverse approach, joint capsule is identified and a 23-g needle inserted from anterior into AC joint beneath capsule
    ▪ Identify joint capsule
    ▪ Insert 23-g needle anteriorly into AC joint beneath joint capsule
    ▪ Inject ~ 2 mL 0.25-0.5% bupivacaine and 1 mL of 40 mg/mL methylprednisolone
    ▪ Widening of joint space seen during injection

Findings and Reporting

· Initial ultrasound findings
· Approach used, such as anterior or posterior approach for glenohumeral joint injection
· Type and size of needle used
· Dose and type of LA, steroid, contrast agent, or other medication used
· Volume, color, viscosity, nature of joint fluid aspirated
· Any adverse event or immediate complication
· Instruction for aftercare

Alternative Procedures/Therapies

· Other
  ◦ Medical therapy
  ◦ Physiotherapy
  ◦ Surgery
  ◦ Extracorporeal shock wave lithotripsy (ESWL) (calcific tendinitis)

POST-PROCEDURE

Expected Outcome

· Mild distension discomfort after contrast or medication injection

Immediate Aftercare

· Perform MR, CT, or conventional arthrography as soon as possible
  ◦ Contrast will be largely absorbed by 30 minutes
· Send aspirate for microbiology, cytology, crystal analysis (need fresh specimen) as appropriate

Subsequent Aftercare

· Avoid shoulder exercise for 24 hours after corticosteroid injection
  ◦ Maximize therapeutic effect
  ◦ Reduce spread of steroid into surrounding tissues

OUTCOMES

Complications

· Most feared complication(s)
  ◦ Infection
· Immediate/periprocedural complication(s)
  ◦ Vasovagal reaction
    ▪ Perform procedures with patient lying down whenever possible
  ◦ Bleeding
    ▪ Avoid vascular injury
    ▪ Check and amend clotting profile if abnormal
    ▪ Use thinnest needle possible and minimalist technique in patients with bleeding diathesis
· Delayed complication(s)
  ◦ Pain 1-2 days after steroid injection due to steroid-related microcrystalline synovitis
    ▪ Will settle with simple oral analgesia
  ◦ Flushing of skin 2-3 days after steroid injection ± cheek erythema
    ▪ Settles within 48 hours
  ◦ Subacromial-subdeltoid bursitis due to local diffusion of calcific material into bursa after treatment of calcific tendinitis
    ▪ Can be very painful
    ▪ Patient should be informed of this complication before procedure
    ▪ Routine injection of steroid-lignocaine mixture into bursa after procedure
    ▪ Oral analgesia and antiinflammatory medication

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SHOULDER PROCEDURES

Needles and Syringes for MR Shoulder Arthrography

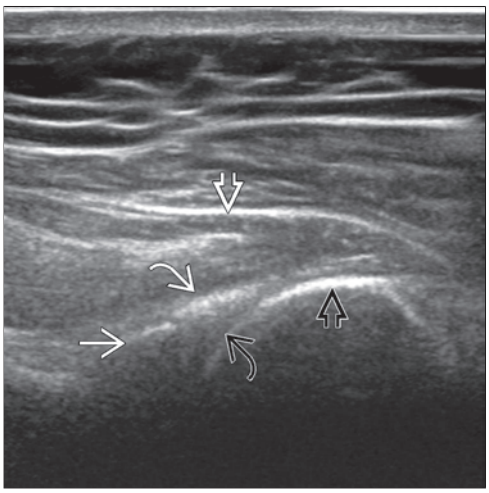


(Left) *Clinical photo shows 22-g spinal needle for intraarticular puncture and injection, 1 mL syringe for drawing MR contrast (which is later added to a 10 mL syringe containing saline) and a 5 mL syringe for local anesthesia.* ***(Right)*** *Clinical photo shows positioning for posterior glenohumeral joint injection. Patient is lying in a comfortable semiprone position with the arm externally rotated and abducted. The ipsilateral upper chest and arm are resting on a pillow.*

Glenohumeral Joint Injection via Posterior Approach



Glenohumeral Joint Injection via Posterior Approach

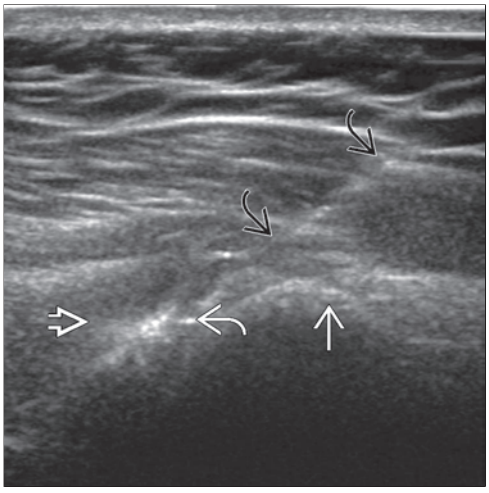


(Left) *Oblique longitudinal ultrasound along the musculotendinous junction of the infraspinatus shows the humeral head, glenohumeral joint, glenoid labrum, and the glenoid bone.* ***(Right)*** *Clinical photo shows the transducer placed transversely across the posterior glenohumeral joint, along the axis of the infraspinatus musculotendinous junction. The injection needle is being introduced from lateral to medial using a long-axis approach.*

Glenohumeral Joint Injection via Posterior Approach

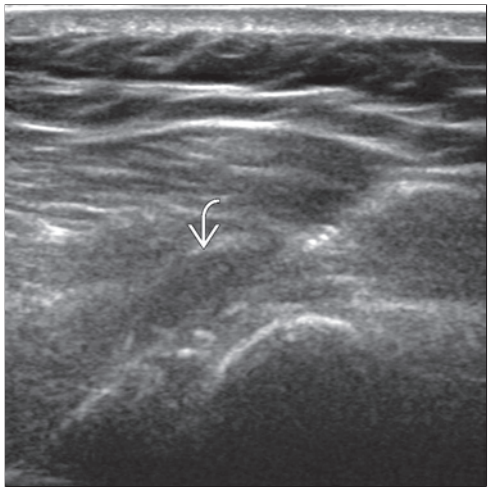


Glenohumeral Joint Injection via Posterior Approach



(Left) *Ultrasound of the same patient shows the tip of the 22-g spinal needle at the posterior glenohumeral joint between the posterior labrum and the humeral head. The needle is introduced in a longitudinal approach.* ***(Right)*** *Ultrasound of the same patient taken after the injection of 14 mL contrast shows further distension of the glenohumeral joint.*

Glenohumeral Joint Injection via Posterior Approach



Glenohumeral Joint Injection via Rotator Interval Approach

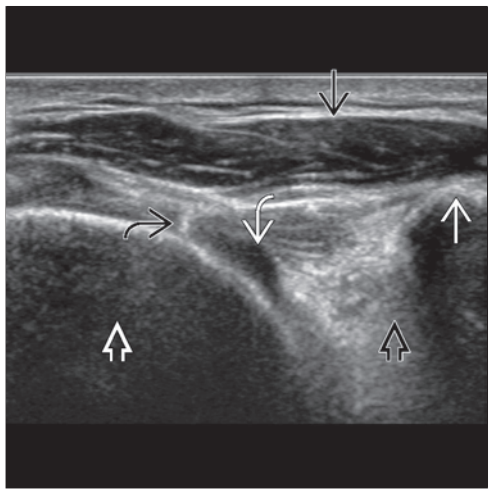


Glenohumeral Joint Injection via Rotator Interval Approach

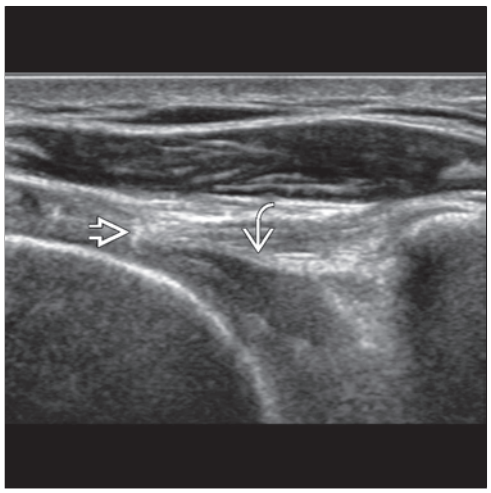


(Left) *Clinical photo shows patient positioning for a rotator cuff interval approach to the glenohumeral joint. Patient lies supine with arm rotated slightly externally and palm facing upward. Avoid extreme external rotation of the arm.* ***(Right)*** *Clinical photo shows transducer placed transversely over the rotator cuff interval. The spinal needle (22-g) is introduced almost perpendicularly into the joint using a short-axis approach.*

Glenohumeral Joint Injection via Rotator Interval Approach

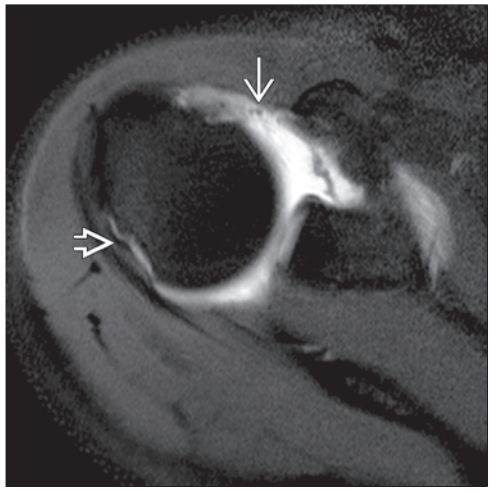


Glenohumeral Joint Injection via Rotator Interval Approach

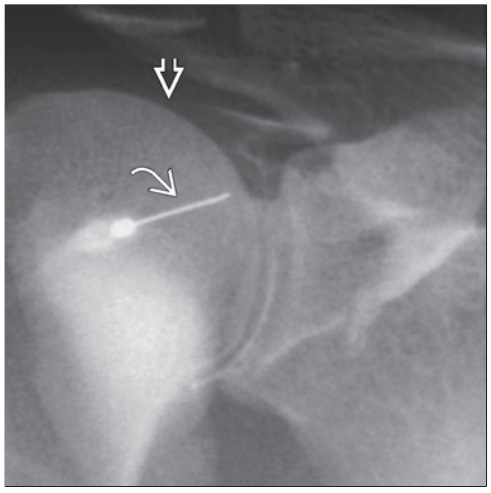


(Left) *Transverse ultrasound taken during injection shows the needle tip positioned at the superomedial portion of humeral head at the rotator cuff interval. A small amount of contrast has been injected. Note the coracoid process, glenoid bone, humeral head, and deltoid muscle.* ***(Right)*** *Transverse ultrasound of the same patient shows the spinal needle tip and further distension of the glenohumeral joint. In general, 10-18 mL of contrast is injected, but the volume is determined by patient's comfort level and resistance to injection.*

Glenohumeral Joint Injection via Rotator Interval Approach



Glenohumeral Joint Injection via Rotator Interval Approach



(Left) *Axial MR arthrogram T1WI FS of the same patient shows satisfactory glenohumeral joint distension. There is a small Hill Sach deformity. Two tiny air bubbles are present in the nondependent portion of the glenohumeral joint.* ***(Right)*** *Frontal radiograph of the shoulder taken during fluoroscopic-guided contrast injection via rotator interval approach shows a 22-g spinal needle contacting the superomedial portion of the humeral head.*

SHOULDER PROCEDURES

Glenohumeral Joint Aspiration



Subacromial Subdeltoid Bursa Injection

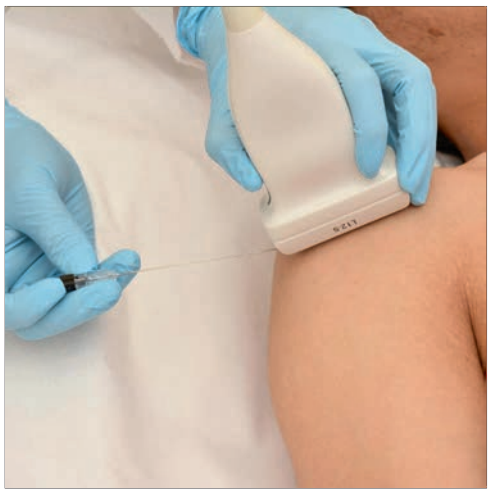


(Left) *Clinical photo of a patient with septic arthritis shows aspiration of purulent fluid ⇨ from the glenohumeral joint via an anterior approach. The approach for joint aspiration is the similar to that for joint injection.* ***(Right)*** *Clinical photo shows positioning for subacromial-subdeltoid bursal injection (lateral approach), which is the most commonly used approach. The probe is positioned along the long axis of the supraspinatus tendon with the needle introduced in a lateral to medial direction.*

Subacromial Subdeltoid Bursa Injection

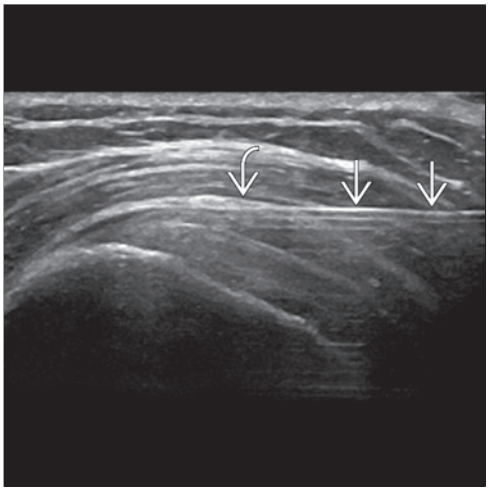


Subacromial Subdeltoid Bursa Injection

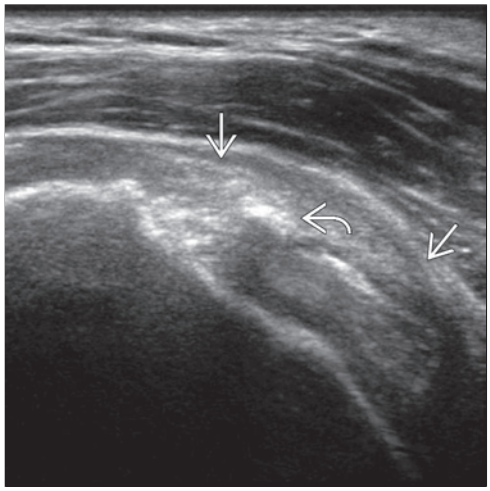


(Left) *Clinical photo shows the positioning for subacromial-subdeltoid bursal injection (superior approach). This approach can be used if fluid has been collected mainly in the cranial part of the bursa.* ***(Right)*** *Clinical photo shows positioning for subacromial-subdeltoid bursal injection (anterior approach). The transducer is positioned in an axial plane at the front of the shoulder, and the needle is advanced in a lateromedial direction.*

Subacromial Subdeltoid Bursa Injection

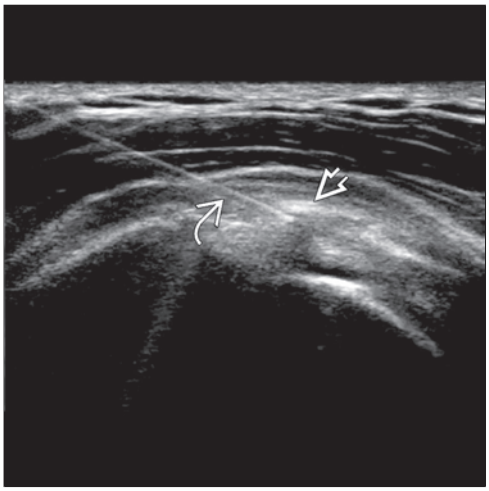


Lavage and Aspiration for Calcific Tendinitis by Single-Needle Technique



(Left) *Longitudinal ultrasound shows the insertion of a 20-g needle ➔ into the subacromial-subdeltoid bursa with the pathway almost parallel to the transducer. Note the distension of the bursa during injection ➔.* ***(Right)*** *Longitudinal ultrasound shows moderate-severity calcific tendinitis of the supraspinatus tendon ➔. The largest calcification ➔ is targeted for aspiration.*

Lavage and Aspiration for Calcific Tendinitis by Single-Needle Technique

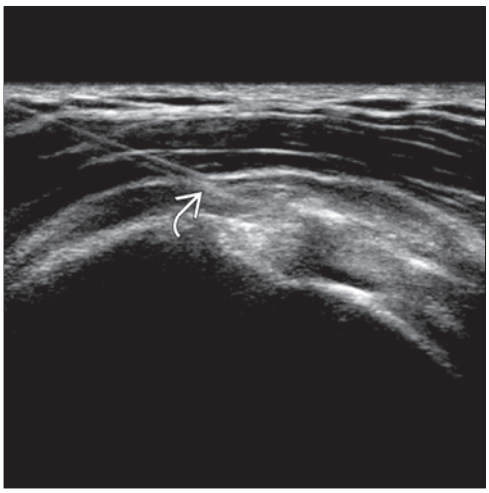


Lavage and Aspiration for Calcific Tendinitis by Single-Needle Technique

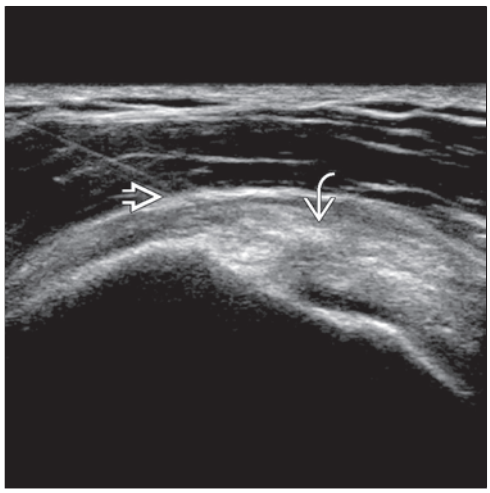


(Left) *Longitudinal ultrasound shows an 18-g needle inserted into the largest calcification within the distal supraspinatus tendon, followed by both rotational and "to and fro" movement of the needle to grind the calcification.* ***(Right)*** *Longitudinal ultrasound shows the tip of the needle positioned at different positions within and around the largest calcification with the aim of fragmenting the calcification for easier aspiration.*

Lavage and Aspiration for Calcific Tendinitis by Single-Needle Technique

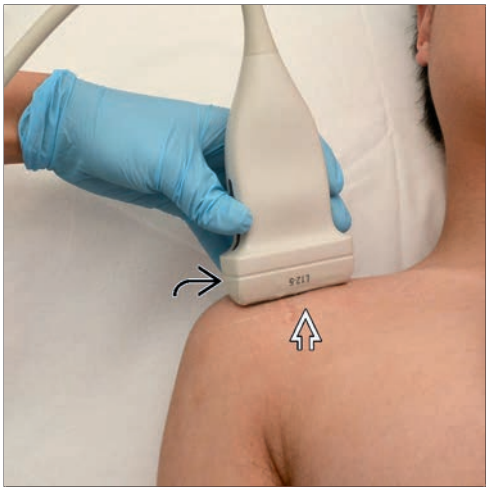


Lavage and Aspiration for Calcific Tendinitis by Single-Needle Technique

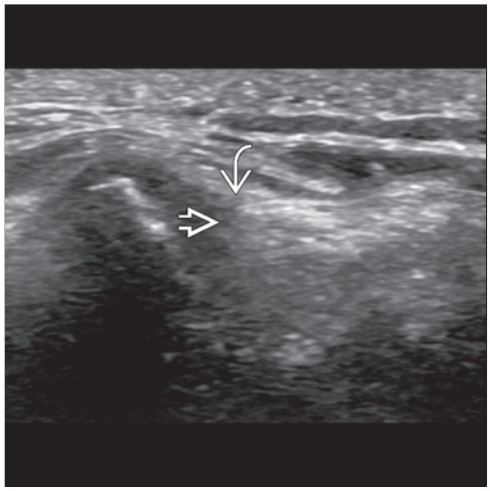


(Left) *Longitudinal ultrasound shows aspiration of the calcific content along the 18-g needle, which is connected to a syringe containing a saline-lignocaine mixture. Lavage followed by aspiration was performed in series.* ***(Right)*** *Longitudinal ultrasound shows reduction in size of the targeted calcification after lavage and aspiration. The needle tip is repositioned in the subacromial-subdeltoid bursa for bursal injection of steroid and long-acting local anesthetic to minimize crystal-induced bursitis.*

Acromioclavicular Joint Injection

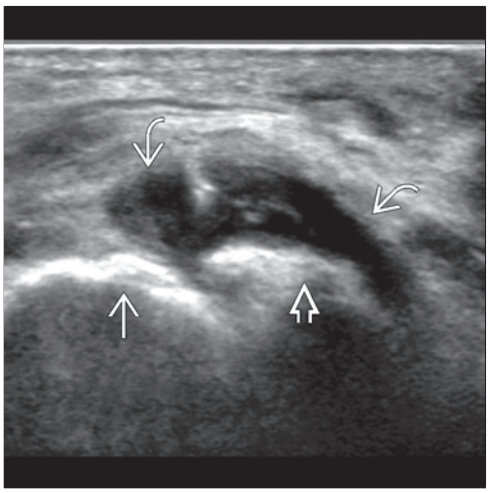


Acromioclavicular Joint Injection

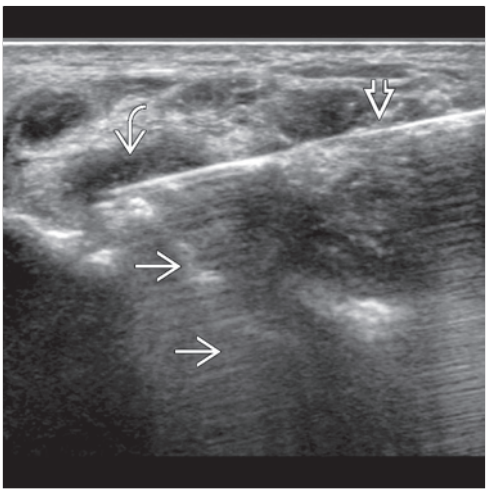


(Left) *Clinical photo shows the positioning of the transducer over the superior aspect and along the short axis of the acromioclavicular joint. The point of needle insertion is anterior to the acromioclavicular joint.* ***(Right)*** *Using a transverse approach, the joint capsule is identified and a 23-g needle inserted anteriorly into the acromioclavicular joint beneath the capsule. Two mL 0.25-0.5% bupivacaine and 40 mg steroid are injected into the acromioclavicular joint.*

ELBOW PROCEDURES



Longitudinal ultrasound shows the distended posterior elbow recess superficial to the humerus and olecranon process. Aspiration was indicated to exclude infection or crystal arthropathy.



Longitudinal ultrasound of same patient shows an 18-g spinal needle with reverberation artifacts within the effusion. The posterior recess is partially collapsed.

PRE-PROCEDURE

Indications

- Intraarticular aspiration
  - Suspected septic arthritis or crystal arthropathy
- Intraarticular injection of contrast or medication
  - Arthrography (CT or MR)
  - Medication to relieve pain or inflammation
    - Steroid injection to reduce inflammation in either inflammatory osteoarthritis or inflammatory arthritis such as rheumatoid arthritis
  - Radiosynovectomy
    - Radioactive isotope (e.g., yttrium 90) injection into joint for radioablation of synovitis in hemophiliac patients or inflammatory joint disease
    - Particularly useful in hemophiliac patients to reduce frequency of joint hemarthroses
      - In hemophilia, synovitis leads to recurrent hemarthroses which leads to synovial hypertrophy and synovitis; this cycle of progressive deterioration leads to end-stage arthropathy
- Paraarticular aspiration
  - Ganglion cyst aspiration
- Paraarticular soft tissue injection
  - For common extensor tendon origin (CETO) or common flexor tendon origin (CFTO) tendinosis
  - Dry needling, steroid injection, prolotherapy, autologous blood injection, platelet-rich plasma (PRP) injection
- Biopsy of synovium/intraarticular soft tissue mass

Contraindications

- Local sepsis

Getting Started

- Things to check
  - Time-out procedure (patient identity, type and side of procedure)
  - Informed consent form signed and risk of procedure explained
  - Allergy history
  - Sedation if required
- Medications
  - Local anesthetic for skin (3 mL, 1% lignocaine)
  - Local anesthetic for intraarticular injection
    - 1-2 % lignocaine or 0.25-0.5% bupivacaine (Marcaine)
  - Steroid
    - 40 mg/mL methylprednisolone (Depo-Medrol)
  - Contrast
    - CT arthrogram: 10 mL iodinated contrast (Omnipaque 300 mg/dL ± 0.1 mL of 1:1000 epinephrine)
    - MR arthrogram: 10 mL diluted gadolinium (0.1 mL gadolinium in 10 mL normal saline)
- Equipment list
  - Sterile set
  - Spinal needle 20 to 22-g
  - Thin (8.5 Fr) extension tubing (0.4 mL dead space if 25 cm long)
  - Syringe; coaxial needle or biopsy needle
  - Sterile bottles, specimen bottles

PROCEDURE

Procedure Steps

- **Intraarticular aspiration or injection**
  - General advice irrespective of approach used
    - Flush syringe and injection tubing to avoid injection of bubbles
    - If needle tip is difficult to see during insertion, move needle slightly in and out under real-time imaging to confirm position of needle tip
    - Aspirate as much fluid as possible for decompression
    - If joint fluid is too viscous, consider using a larger bore needle, e.g., 16- or 18-g
    - If insufficient aspirate despite good needle tip position, rotate needle 180° to change bevel position or else retract slightly and reposition needle tip

ELBOW PROCEDURES

Key Facts

Pre-Procedure

- **Indication**
  - Intraarticular aspiration of joint fluid or injection of contrast or medication
  - Tendinosis or ligament injury treatment (dry needling, steroid injection, prolotherapy, autologous blood injection, platelet-rich plasma injection)
  - Paraarticular cyst or bursal aspiration
  - Synovial or intraarticular soft tissue mass biopsy

Procedure

- **Intraarticular aspiration or injection**
  - Posterior (trochlear-olecranon) approach (preferable)
  - Anterolateral (radiocapitellar) approach
- **Tendinosis or ligament injection**
  - Identify abnormal hypoechoic area of tendinosis ± anechoic cleft-like intrasubstance tears within area of tendinosis
  - Treatment is aimed at these areas
- Dry needling: "To and fro" movement of needle within area of tendinosis for 1 minute
- Autologous blood or platelet-rich plasma injection
- Corticosteroid injection
  - Inject peritendinous tissue rather than tendon substance
  - Reduces peritendinitis but has no therapeutic effect on tendinosis per se
- **Paraarticular cyst aspiration**
  - > 19-g needed for more viscous content

    - If still insufficient aspirate, consider irrigating joint with saline; saline wash is then aspirated and labeled as joint wash
  - Leave needle either free in joint or resting on articular cartilage, but do not push needle into articular cartilage
  - Free flow of fluid with low pressure during injection helps confirm intraarticular position of needle tip
  - Avoid active exercise to prevent any leakage of solution along needle track for ~ 5-10 minutes
- Posterolateral approach (trochlear-olecranon articulation)
  - Preferable, as no major neurovascular structures posterolaterally
  - Position patient with elbow flexed to 90° and forearm fully pronated
  - Position probe sagittally along posterior part of elbow
  - Move transducer laterally until triceps is just out of view
    - Landmarks: Olecranon fossa of humerus, posterior fat pad, olecranon
- Anterolateral approach (radiocapitellar articulation)
  - More ergonomic and convenient in terms of patient positioning, but more difficult and time-consuming to find injection site
    - Potential risk to radial neurovascular bundle
    - Needle tip placed into smaller space
  - Patient sits next to table with flexed elbow resting on table and lateral aspect uppermost
  - Position probe longitudinally along lateral part of elbow
    - Landmarks: Radial head and capitellum

· **Paraarticular aspiration**

- Needle advanced into paraarticular cyst or collection under real-time imaging
- 21-g needle for ganglion cyst aspiration
  - 18-g or larger needle for more viscous content
- ± hyaluronidase (150 units in 1 mL) prior to aspiration if too viscous ± steroid (1 mL 40 mg methylprednisolone) injection after aspiration

· **Tendinosis treatment**

- Common procedure for CETO tendinosis, less common for CFTO tendinosis
- Now widely accepted that tendinosis is not an inflammatory condition but a fibroblastic and vascular response to failure of normal tendon repair
- Most patients respond to conservative treatment
- Intervention indicated in patients refractory to conservative treatment suffering from chronic pain and disability
- Superficial position of CETO or CFTO is ideally suited to ultrasound-guided injection
- Check particularly whether any tear is present on preliminary ultrasound examination as this will have bearing on treatment choice
- Position probe over affected tendon area including tendinosis or partial tear
- 21- to 25-g needle advanced into tendon under real-time imaging
- **Dry needling: Repeated fenestration of local tendinosis**
  - Fenestration means making holes (fenestra is Latin word for "window")
  - Initially infiltrate local anesthetic around tendon
  - Position needle tip centrally within most severe area of tendinosis
  - Move needle tip "to and fro" within area of tendinosis for 1 minute to create fenestrations, fiber disruption, and internal bleeding
  - Often followed by autologous blood or platelet-rich plasma injection
- **Corticosteroid injection**
  - Historically, steroid is used frequently in treatment of CETO or CFTO tendinosis
  - Local infiltration of 1 mL triamcinolone acetonide (10 mg/mL) and 1 mL 2% lignocaine
  - Inject peritendinous tissues rather than tendon itself
  - Can repeat injection once after 2 weeks
  - Leads to significant improvement in pain and grip strength at 6 weeks time, though no significant long-term difference compared with local anesthetic injection or conservative treatment

- Helps to treat peritendinitis associated with tendinosis, though no known beneficial effect on tendinosis per se
- **Prolotherapy**
  - Treatment of tendinosis, partial tendon tear, or ulnar collateral ligament tear
  - Irritant solution (proliferant, e.g., hyperosmolar dextrose) incites inflammatory response with fibroblast proliferation and collagen repair
  - 0.5 mL dextrose solution (4 mL of 50% dextrose + 4 mL normal saline and 2 mL lignocaine) injected into tendon where there are features of tendinosis or tear
  - Additional 2 mL total of solution injected near bone at supracondylar ridge and annular segment
  - Leads to significant improvement in elbow pain score, grip strength, and range of movement at 8 weeks time
- **Autologous blood**
  - Indicated for tendinosis, partial tendon tear, or ulnar collateral ligament tear
  - First identify any discrete tear, focal tendinosis, or discrete area of neovascularity
  - Draw 2 mL of autologous blood from contralateral antecubital vein and gently shake to prevent clotting
  - Infiltrate 2 mL of bupivacaine (0.25%) along surface of tendon or ligament
  - Insert needle into most abnormal site of tendon or ligament
    - Usually preceded by dry needling of tendon or ligament
  - Repeat procedure once after 4 weeks time
  - Leads to significant reduction in elbow pain score
- **Platelet rich plasma (PRP) injection**
  - Indicated for tendinosis, partial tendon tear, or ulnar collateral ligament tear
  - PRP contains fibroblast growth factors, which facilitate healing
  - 5 mL of leukocyte-rich PRP injected
  - Apply bandage and moist heat packs every 3 hours for 15 minutes duration for first 24 hours after injection
  - PRP efficacy is greater for CETO tendinosis compared to Achilles and patellar tendinosis
    - For CETO tendinosis: 81% improvement at 6 months and 93% improvement at 26 months
  - 88% of partial ulnar collateral ligament tears are fully and successfully treated by 12 weeks

· **Intraarticular soft tissue biopsy**
- Use coaxial needle to prevent multiple skin punctures
- If biopsy of intraarticular mass, usually aim directly to mass under real time ultrasound guidance

Findings and Reporting

· Depends on interventional procedure performed, but consider reporting on these aspects
- Initial ultrasound findings
  - Do not perform any interventional procedure without first making full assessment of ultrasound findings
  - Large/moderate/small amount of joint fluid
- Type and size of needle used
- Amount and strength of local anesthetic used
- Volume, color, and viscosity of joint fluid aspirated
  - If biopsy, record if only friable tissue obtained
  - If injection, record volume and concentration of contrast/medication injected
- Immediate complication, e.g., bleeding

POST-PROCEDURE

Expected Outcome

· Aspiration of joint fluid
- Immediate decrease in distension pain and swelling

· Intraarticular injection of medication or contrast
- May experience synovitis discomfort for 1-2 days

· Paraarticular tendon/ligament injection
- Slow improvement over 1-2 weeks

Immediate Aftercare

· Perform MR, CT, or conventional arthrography as soon as possible after injection as contrast will be mostly absorbed within 30 minutes

· Send aspirate for microbiology, cytology, crystal analysis (need fresh specimen) as appropriate

Subsequent Aftercare

· Avoid exercise for 24 hours after corticosteroid injection, to maximize therapeutic effect and reduce spread of steroid into surrounding tissues

· After treatment of tendinosis or ligament injury, refrain from excessive loading of tendon during week following procedure
- Avoid taking anti-inflammatory medication, which may decrease healing process

OUTCOMES

Complications

· Most feared complication(s)
- Infection, e.g., septic arthritis
- Extravasation of contrast/medication
  - Steroid/radiosynovectomy: Fat pad atrophy, skin atrophy, skin depigmentation

· Immediate/periprocedural complication(s)
- Bleeding, especially for those with bleeding diathesis
- Capsular rupture
- Allergy to contrast and medication
- Neurovascular bundle injury; both ulnar nerve injury from posterior approach or radial nerve injury from anterior radiocapitellar approach are rare

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2. Podesta L et al: Treatment of partial ulnar collateral ligament tears in the elbow with platelet-rich plasma. Am J Sports Med. 41(7):1689-94, 2013
3. Rabago D et al: Hypertonic dextrose and morrhuate sodium injections (prolotherapy) for lateral epicondylosis (tennis elbow): results of a single-blind, pilot-level, randomized controlled trial. Am J Phys Med Rehabil. 92(7):587-96, 2013
4. Vuillemin V et al: Musculoskeletal interventional ultrasonography: the upper limb. Diagn Interv Imaging. 93(9):665-73, 2012

Posterior Approach



Posterior Approach



(Left) *Posterior approach shows the flexed elbow either resting on a table or lying on a bed. This approach is common and convenient for the patient. However, it provides less space for redirecting the needle position.* ***(Right)*** *Posterior approach shows an alternative palm down, wrist extended, and elbow flexed position. This approach allows a wider space for needle puncture and adjustment. This position requires a high level of patient cooperation.*

Anterolateral Approach

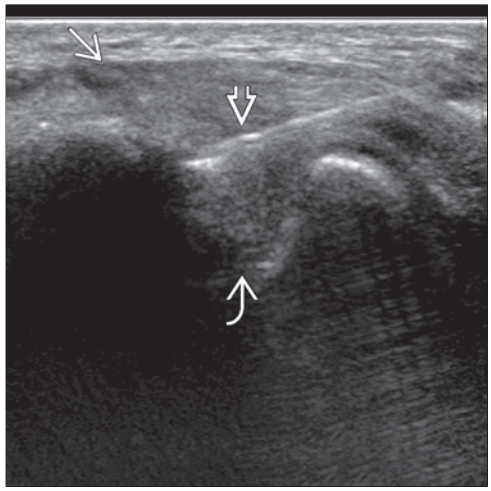


Common Extensor Tendon Origin Injection

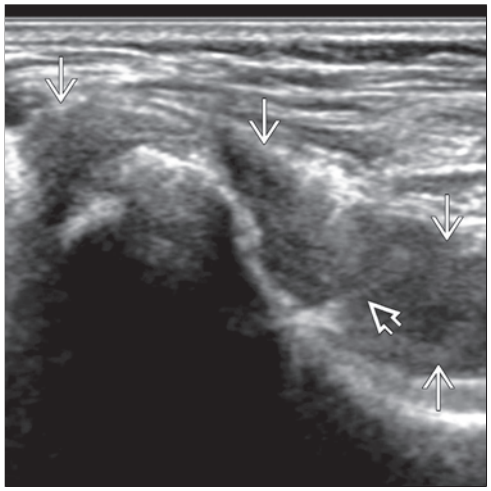


(Left) *Anterolateral approach to radiocapitellar articulation shows how the elbow is flexed and resting on a table. This approach is more difficult and time consuming. The joint space is smaller and the radial nerve and artery are close to the needle path.* ***(Right)*** *Clinical photograph shows the approach to the common extensor tendon origin (CETO) injection with the elbow slightly flexed and resting on a table under ultrasound guidance. The needle is then advanced into the CETO.*

Ultrasound-Guided Radiosynovectomy



Ultrasound-Guided Radiosynovectomy



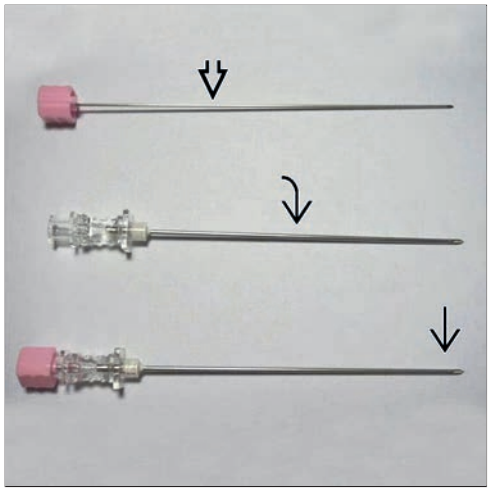
(Left) *Ultrasound-guided radiosynovectomy of a hemophiliac joint is shown using a 23-g spinal needle* ➔ *within the moderately eroded lateral radiocapitellar joint* ➔ *for radioactive yttrium injection. Moderate synovial proliferation* ➔ *is present.* ***(Right)*** *Ultrasound-guided radiosynovectomy of a hemophiliac patient is shown with the tip of the 23-g spinal needle at the posterior aspect of the mildly eroded distal humerus* ➔*. The posterior recess is distended with thickened hypoechoic synovium* ➔*.*

ELBOW PROCEDURES

Ultrasound-Guided Aspiration/ Injection Sterile Set

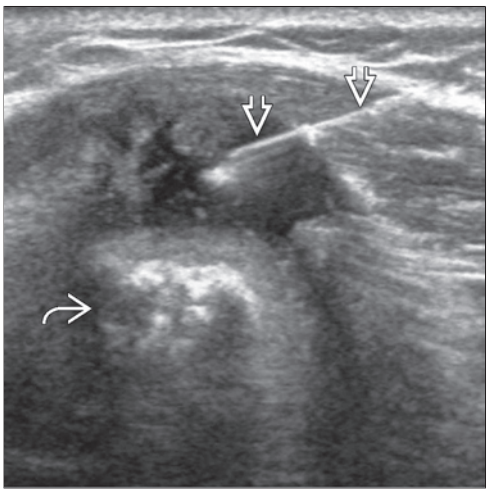


Needle Used for Drainage

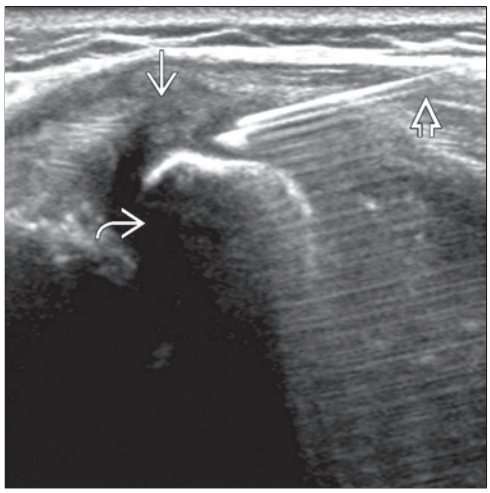


(Left) *Photograph of set up used for injection of contrast or medication shows a syringe with 3-way connector and extension tubing, specimen bottle, syringe with local anesthetic, forceps, sterile solution, and 22-g spinal needle.* ***(Right)*** *Clinical photo shows a commonly used spinal needle with a sharp bevelled edge used to puncture skin and soft tissue. The stylet is removed from the outer sheath only in the joint or cyst.*

Ultrasound-Guided Aspiration

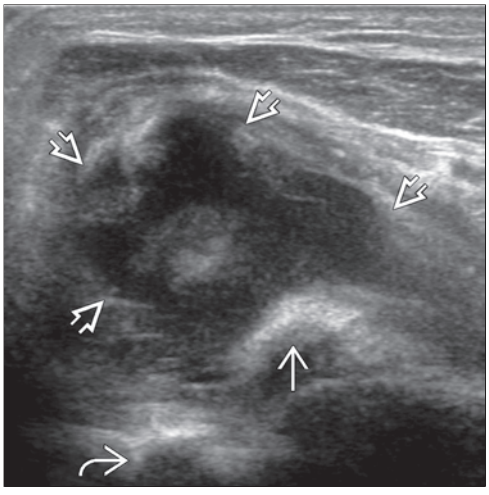


Ultrasound-Guided Aspiration

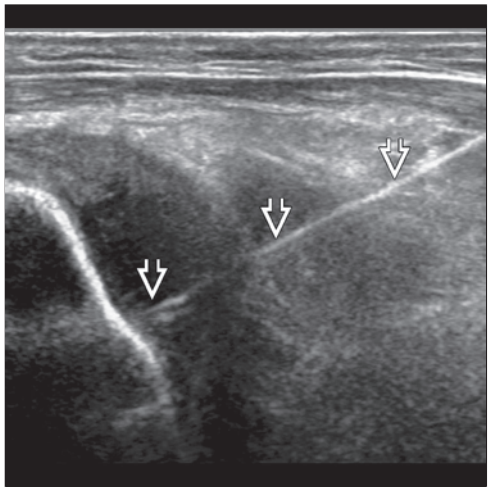


(Left) *Transverse ultrasound shows aspiration of a posterior elbow recess in a rheumatoid patient. The recess has been punctured with a 21-g spinal needle under real-time imaging. There is some cortical erosive change at the olecranon tip.* ***(Right)*** *Transverse ultrasound during aspiration shows the needle is shown in the previously distended posterior recess. The recess has now almost completely collapsed, leaving a small amount of residual synovial thickening. The more distal part of the olecranon is normal.*

Ultrasound-Guided Aspiration

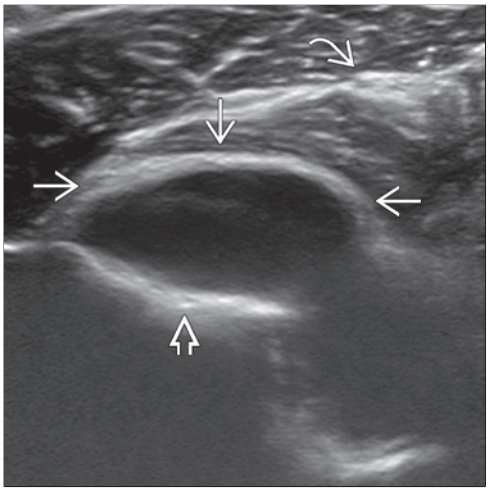


Ultrasound-Guided Aspiration

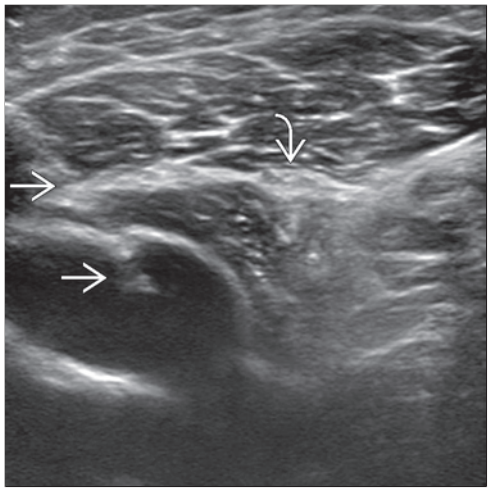


(Left) *Ultrasound shows a distended anterior elbow recess superficial to the proximal ulna and radius in a rheumatoid patient with suspected superimposed infection.* ***(Right)*** *Ultrasound during ultrasound-guided aspiration of the anterolateral aspect of the same elbow with the 21-g spinal needle. Most of the fluid could be aspirated. Microbiology culture showed no bacterial growth.*

Ultrasound-Guided Aspiration and Injection

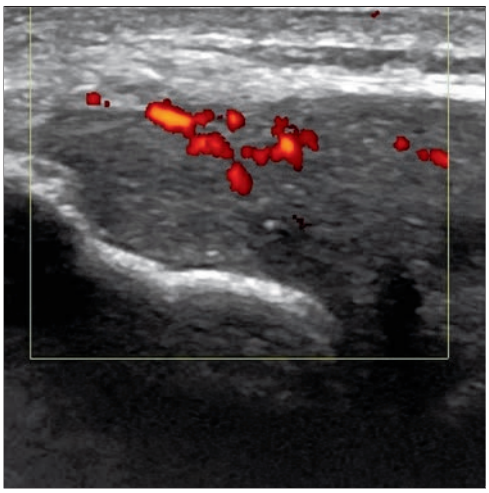


Ultrasound-Guided Aspiration and Injection

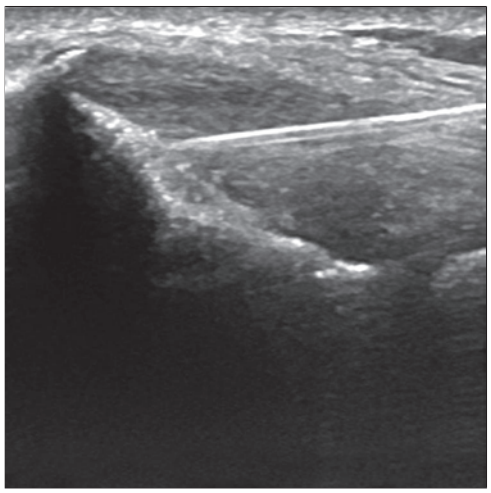


(Left) *Ultrasound shows a loculated ganglion cyst ➔ anterior to the radial neck ➔. The posterior interosseous nerve (PIN) ➔ at this level is immediately alongside the supinator muscle lying above the ganglion cyst. (Courtesy S. James, MD.)* ***(Right)*** *Ultrasound during injection of steroid after almost complete cyst aspiration using a 22-g spinal needle ➔. The needle path has been selected to avoid injury to the PIN ➔. Steroid injection helps decrease pericystic inflammation and reduces the likelihood of ganglion cyst recurrence. (Courtesy S. James, MD.)*

Ultrasound-Guided Injection

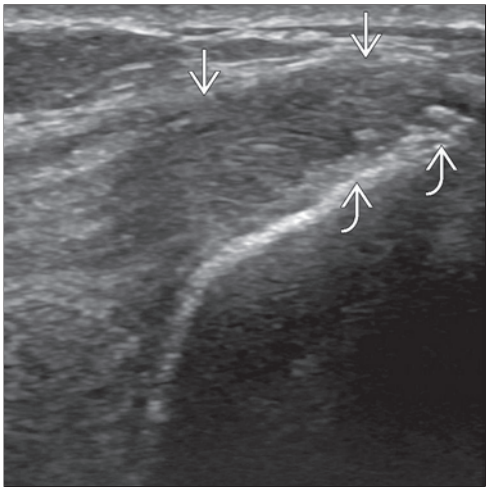


Ultrasound-Guided Injection

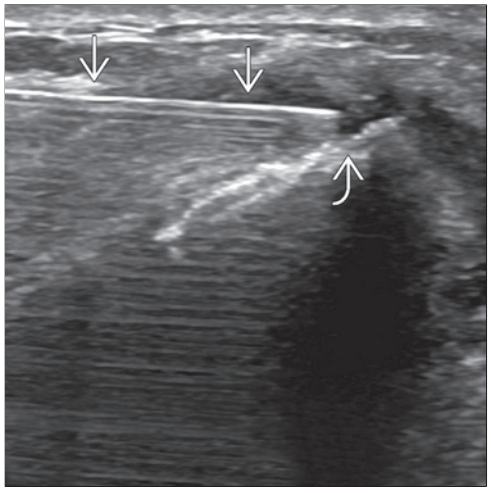


(Left) *Preliminary longitudinal power Doppler ultrasound shows severe tendinosis with hyperemia at the common extensor tendon origin (CETO).* ***(Right)*** *Longitudinal ultrasound shows ultrasound-guided injection of 1 mL (40 mg/mL) methylprednisolone with 0.5 mL (1%) lignocaine deep to the CETO using a 22-g spinal needle after dry needling for 1 minute. Dry needling helps to create fenestrations, disrupts tendon fibrillar structure and promotes internal bleeding.*

Ultrasound-Guided Injection



Ultrasound-Guided Injection



(Left) *Preliminary longitudinal ultrasound scan shows severe common flexor origin (CFTO) tendinosis with severe hypoechoic changes and loss of the normal fibrillation ➔ with insertional bony irregularity ➔ at the CFTO.* ***(Right)*** *Longitudinal ultrasound shows ultrasound-guided injection of 1 mL (40 mg/mL) methylprednisolone with 0.5 mL (1%) lignocaine deep to the CFO ➔ using a 23-g spinal needle ➔ after dry needling for 1 minute. Dry needling creates a controlled tendon injury in order to stimulate a healing response.*

HAND AND WRIST PROCEDURES

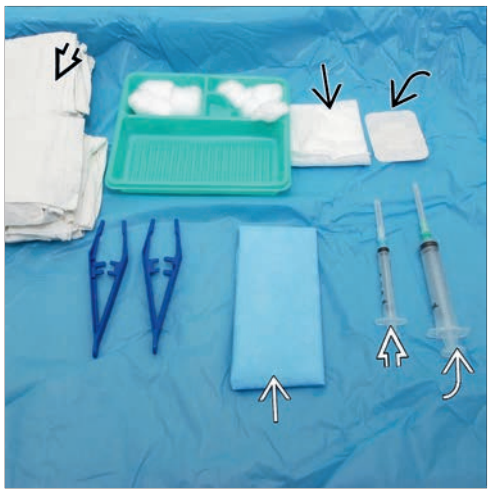
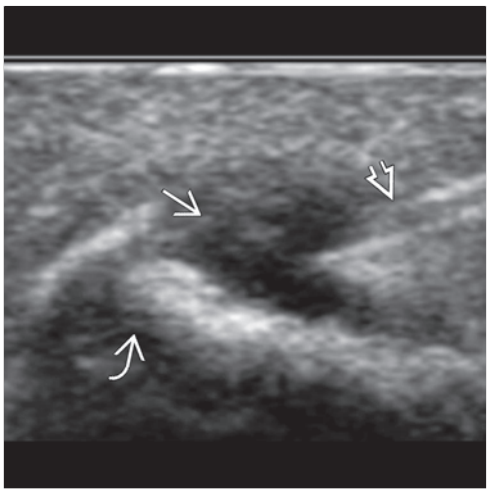


Photo of setup for aspiration and injection shows an ultrasound probe cover, 3 mL syringe with 23-g needle, 5 mL syringe with 21-g needle, sterile towel, gauze, and bandage.



Longitudinal ultrasound of thumb shows a small ganglion on the lateral aspect of the metacarpal head. A 21-g needle tip lies within the ganglion prior to aspiration of ganglion contents.

PRE-PROCEDURE

Indications

- Aspiration or intraarticular injection
  - Suspected septic arthritis or crystal arthropathy
  - Medication for control of inflammation or symptom relief
  - MR, CT, or conventional arthrography
- Ganglion cyst
  - Aspiration for symptom relief
  - Ultrasound cannot predict cyst content viscosity
- Tendon disease (tenosynovitis or tendinosis)
  - Aspiration for suspected infective tenosynovitis
  - Injection for symptom relief and to improve function
- de Quervain disease: Injection or tenotomy for symptom relief and to improve function
- Trigger finger: Annular pulley injection or percutaneous pulley release for symptom relief and to improve function
- Carpal tunnel syndrome: Injection for symptom relief

Getting Started

- Things to check
  - Time-out procedure (check patient name, type and side of procedure)
  - Signed informed consent
  - Discuss risk of infection, allergy, bleeding, and tissue injury
  - Sedation, if required
- Medications
  - Local anesthetic for skin (2-3 mL 1% lignocaine)
  - Local anesthetic for intraarticular injection
    - 1-2% lignocaine or 0.25-0.5% bupivacaine (Marcaine)
  - Steroid
    - Short (hydrocortisone), medium-acting (methylprednisolone), or long-acting (dexamethasone)
    - Equivalent dosage: Hydrocortisone 20 mg = methylprednisolone 5 mg = dexamethasone 0.75 mg
  - Contrast
    - CT arthrography: Iodinated contrast, e.g., Omnipaque 300 ± 0.1 mL of 1:1,000 epinephrine
    - MR arthrography: Dilute gadolinium (1:100), e.g., 0.1 mL gadolinium in 10 mL normal saline solution
- Equipment list
  - Sterile set
  - Spinal or intravenous needle 18- to 25-g
  - Thin extension tubing (250 mm, 8.5 Fr, 0.4 mL dead space)
  - Syringes for local anesthetic, aspiration, and injection
  - Sterile bottle and specimen bottles

PROCEDURE

Joint Aspiration or Injection

- General clues irrespective of joint aspirated or injected
  - Sterile technique: Skin and underlying soft tissues anesthetized at puncture site
  - Do full ultrasound assessment preprocedure, planning best approach that will avoid neurovascular or tendon injury
  - Use free-hand technique to advance 25-g needle into joint space using continuous ultrasound guidance
    - Avoid puncture of neurovascular bundle by carefully planning approach
  - Can use long-axis (preferable) or short-axis approach
  - Use smallest needle possible (23- to 27-g) that will comfortably reach joint
    - Larger needle (19-g) used for purulent fluid aspiration
  - Ensure on real-time imaging that needle tip is within joint space and directed toward any joint fluid
  - Avoid injection of bubbles by first flushing syringe and tubing
  - Free flow of fluid with low-pressure injection helps confirm intraarticular position of needle tip
  - If free fluid flow is not present, rotate or slightly realign needle
  - Continue monitoring joint on real-time imaging during procedure with realignment of needle if necessary

Key Facts

Pre-Procedure

- **Indication**
  - Aspiration of joint fluid
  - Intraarticular injection of medication or contrast agent
  - Percutaneous therapy of ganglion cyst, tendon disease, trigger finger, and carpal tunnel syndrome

Procedure

- Joint aspiration or injection
  - Radiocarpal, midcarpal, distal radioulnar joints: Dorsal approach
  - Scaphotrapeziotrapezoid or trapeziometacarpal joints: Dorsoradial approach
- Ganglion cyst aspiration
  - ≥ 19-g needle for more viscous contents
  - No pretest predictor of cyst viscosity
- Tendon disease: Approach depends on site of disease
  - Steroid injection: More commonly used
  - Needle tendon pulley release, platelet-rich plasma (PRP) injection: Less commonly used
- de Quervain disease: Dorsoradial approach
  - Steroid injection more commonly used
  - Needle tendon retinacular release, PRP injection: Less commonly used
- Trigger finger: Palmar approach, short or long axis
  - Steroid injection
  - Percutaneous pulley release
- Carpal tunnel syndrome: Palmar approach
  - Steroid injection seems to produce good symptom relief in short (6 weeks) to medium term (6 months)

- Post injection, apply local pressure and avoid active exercise for ~ 10 minutes to prevent leakage of solution along needle track

· Intraarticular injection of wrist joints
- 25-g intravenous or spinal needle is used
- Radiocarpal joint
  - Dorsal approach via radioscaphoid joint space
  - Place probe in sagittal plane at right angles to joint
  - Enter 1 cm distal to radioscaphoid joint space
  - Direct needle proximally toward articular cartilage of distal radius
  - Once cartilage is contacted, tilt needle vertically to enter center of radioscaphoid joint
- Midcarpal joint
  - Dorsal approach
  - Place probe in sagittal or transverse plane
  - Target either scaphocapitate or triquetrohamate interspaces
- Distal radioulnar joint
  - Dorsal approach
  - Place probe in transverse plane
  - Position needle alongside radial border of ulna head a few mm proximal to distal articular surface and directed toward ulnar head
  - When needle contacts ulnar head, angle it more vertically to insert deeper into joint space
- Scaphotrapeziotrapezoid or trapeziometacarpal joints
  - Dorsoradial approach
  - Place probe in sagittal plane
  - Angle needle 30-45° relative to transducer

Ganglion Cyst Aspiration

· 21-g needle advanced into ganglion under continuous real-time imaging
- ≥ 19-g needed for more viscous content

· Injecting a little lignocaine into ganglion can loosen cyst contents if initial aspirate is dry due to contents being too viscous

· ± pretreatment with hyaluronidase (150 units in 1-2 mL normal saline)
- Hyaluronidase degrades hyaluronic acid, which is macromolecular component of ganglion cyst fluid
- Inject hyaluronidase to ganglion cyst, leave needle in cyst for 15 minutes, and then aspirate

· ± intracystic injection of steroid (methylprednisolone 4-10 mg) post aspiration

· ± fenestration (puncture) of cyst wall with needle several times during procedure
- Allows cyst fluid to leak, reducing likelihood of recurrence

Tendon Disease

· Approach is tailored according to affected tendon segment
- Dorsal or palmar approach
- Probe usually in sagittal plane, avoiding excessive probe pressure, which may efface tenosynovial fluid

· Needle (21-g) advanced to tendon margin under real-time imaging
- Alternatively, can enter periphery of tendon substance and slowly withdraw needle, gently aspirating or injecting fluid

· Steroid (methylprednisolone 4-10 mg) or platelet-rich plasma (PRP, 3 mL) injections are potential treatment options for tendinosis

de Quervain Disease

· Wrist in neutral position resting on a wedge and slightly ulnar deviated
- Axial approach preferable

· Steroid injection, PRP injection, or percutaneous needle tendon retinacular release
- Steroid injection is most commonly used
  - 23-g needle
  - 10 mg methylprednisolone injected into tendon sheath of 1st extensor compartment deep to retinaculum

· If septum is present (40%), inject tendon sheaths of both subcompartments

· Percutaneous dry needling
- Dry needling of tendinosis induces bleeding as well as reparative response
- Converts quiescent nonhealing chronic injury into acute injury with enhanced healing capability and recruitment of reparative stem cells

· PRP injection is less frequently employed than steroid injection

- 20 mL of patient's whole blood is collected and, following manufacturer's instructions, 3 mL of PRP is prepared
- 3 mL PRP is injected into tendon sheath of 1st extensor compartment deep to retinaculum under real-time imaging to ensure even distribution into peritendinous tissues
  - Provides reparative growth factors and stem cells to injured tendon

· No established evidence as to efficacy of 1 treatment over another

Trigger Finger

· Steroid injection or percutaneous release of annular pulley are potential treatment options
- Hand flat on table, palm upwards
- Palmar approach, both axial (best for thumb) and sagittal (best for other fingers) planes are used
- 23-g needle is placed deep to annular pulley
  - 10 mg methylprednisolone injected deep to annular pulley under real-time imaging to ensure good dispersion

· Percutaneous release of annular pulley
- Longitudinal approach
- Insert 19-g intravenous needle deep to annular pulley
  - Needle bent to 15-20° close to hub prior to insertion
  - Rotate bevel sideways to facilitate cutting action
  - Using skin as pivot and downward pressure on attached syringe, cut annular pulley from deep to superficial (i.e., away from tendon)
- Mean procedure time is < 15 minutes
- Outcome is comparable to that of surgical release and non-image-guided percutaneous release
- Much shorter recovery time than surgical release

Carpal Tunnel Syndrome

· Injection is both diagnostic and therapeutic
· Place wrist in slightly dorsiflexed position
· 2 axial volar approaches
- Ulnar route
- Radial route, avoiding radial artery and passing deep to flexor tendons

· Using 23-g needle, steroid (10 mg methylprednisolone) is injected around median nerve under continuous ultrasound guidance
· 60% of patients get moderate to great symptom relief after single injection
- Symptom relief seems to be sustained for short (6 weeks) to medium term (6 months), though few follow-up studies exist

Findings and Reporting

· Depends on interventional procedure performed, but consider reporting on these aspects
- Initial ultrasound findings
  - Do not perform any interventional procedure without first making full assessment of ultrasound findings and reporting clearly on these findings
  - Provide objective (quantitative or semiquantitative) criteria of baseline disease severity, e.g., median nerve caliber or degree of tendinosis/peritendinitis
- Local anesthetic volume and concentration used
- Type and size of needle used
- Volume, color, and viscosity of joint fluid aspirated
- Volume and type of fluid injected
- Unexpected adverse occurrence during procedure, e.g., arterial puncture
  - Report even in absence of immediate complications due to potential for later complications
- Immediate complication, e.g., excessive bleeding

POST-PROCEDURE

Immediate Aftercare

· MR or CT arthrography should be performed as soon as possible after arthrography, as contrast will have largely absorbed in 30 minutes
· Aspirate should be sent, wherever appropriate, for
- Cell count, Gram stain, microscopy and culture (aerobic and anaerobic), and sensitivity
- Crystal analysis and cytology
  - For crystal analysis, send fresh specimen (crystals are dissolved by water, alcohol, or formalin)

Subsequent Aftercare

· Avoid exercise for 24 hours after corticosteroid injection to maximize therapeutic effect and reduce speed of steroid into surrounding tissues
· After tendon therapy such as dry needling, refrain from tendon-loading activity for a week
- Avoid taking anti-inflammatory medication, which may theoretically impair healing process

· For more specific tendon intervention such as PRP injection or ABI
- Rest for 2 weeks with no return to sports activity/ training for 6 weeks

OUTCOMES

Complications

· Most feared complication(s)
- Infection, e.g., septic arthritis
- Injury to neurovascular bundle
  - de Quervain disease
    - Medial branch of superficial radial nerve lies just ulnar to 1st extensor retinaculum
    - Lateral branch of superficial radial nerve crosses over 1st extensor retinaculum from ulnar to radial side
    - Deep branch of radial artery lies deep to 1st extensor compartment
    - Cephalic vein passes superficial and close to 1st extensor retinaculum
- Extravasation of contrast or medication
  - Steroid: Fat atrophy, skin atrophy, skin depigmentation

· Immediate/periprocedural complication(s)
- Bleeding, especially if bleeding diathesis
  - Apply local pressure
- Extravasation of contrast or medication
  - Apply local pressure and rest joint for 10 minutes
- Capsular rupture
- Allergy to injectate

SELECTED REFERENCES

1. Vuillemin V et al: Musculoskeletal interventional ultrasonography: the upper limb. Diagn Interv Imaging. 93(9):665-73, 2012

de Quervain Disease Injection

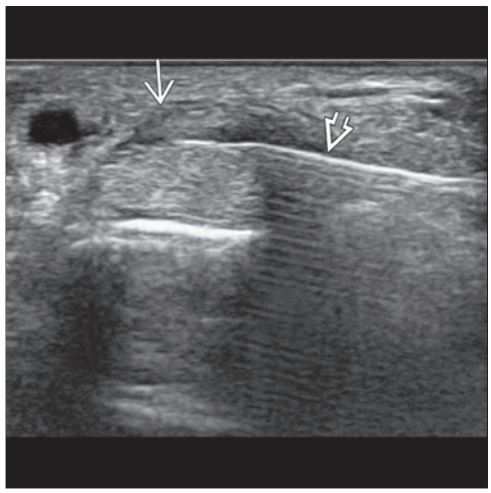


de Quervain Disease Injection

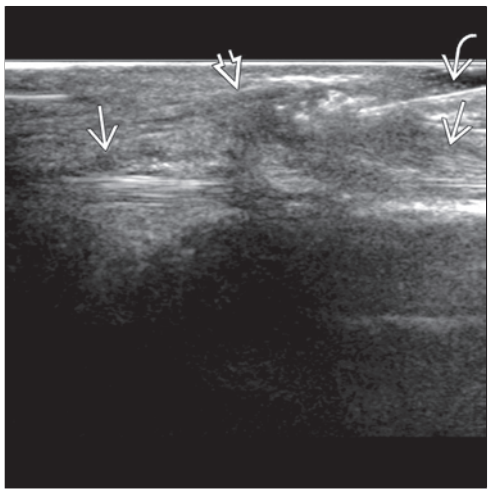


(Left) *Clinical photo shows the longitudinal approach for injection of de Quervain disease. The wrist is resting on a towel wedge with slight ulnar deviation* ***(Right)*** *Clinical photo shows the axial approach for injection of de Quervain disease. If there is a septum present in the 1st extensor compartment (as seen in 40% of subjects), both subcompartments need to be treated.*

de Quervain Disease Injection

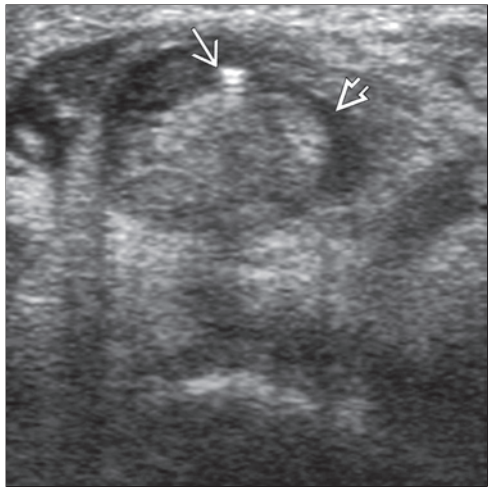


de Quervain Disease Injection



(Left) *Transverse ultrasound of a patient with de Quervain disease shows moderate thickening of the extensor retinaculum ➔ of the 1st extensor compartment. A 23-g intravenous needle ➔ is inserted into the tendon sheath just deep to the retinaculum and 10 mg methylprednisolone injected.* ***(Right)*** *Longitudinal ultrasound shows steroid (10 mg methylprednisolone) being injected into the tendon sheath of 1st extensor compartment ➔ tendons deep to the retinaculum ➔ via a 23-g needle ➔.*

de Quervain Disease Injection



Carpal Tunnel Injection



(Left) *Transverse ultrasound of a patient with de Quervain disease shows a 23-g intravenous needle ➔ advanced into the tendon sheath deep to the thickened retinaculum and steroid (10 mg methylprednisolone) being injected into tendon sheath ➔.* ***(Right)*** *Clinical photo shows steroid (10 mg methylprednisolone) injection treatment for carpal tunnel syndrome using a transverse approach. The needle (21- or 23-g) is inserted on the ulnar side. This ulnar approach is more common than the radial approach.*

Trigger Finger Injection

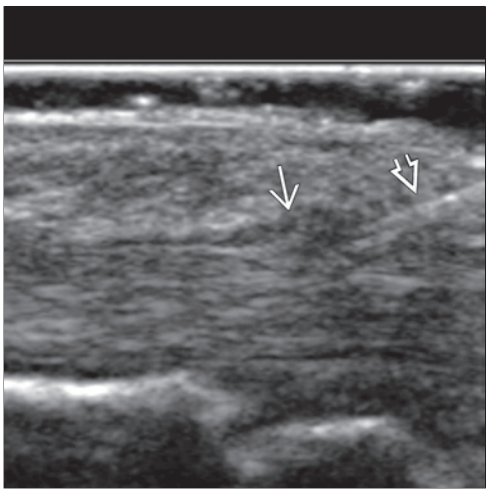


Trigger Finger Injection

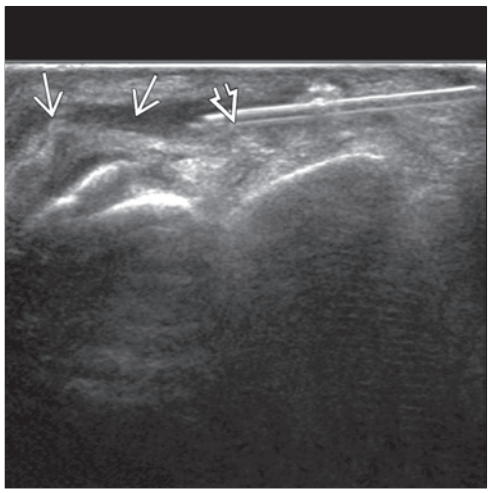


(Left) *Clinical photo shows the longitudinal palmar approach for annular pulley injection. This is the most commonly used approach, as access to the area between the pulley and the flexor tendons is easiest. It is also the preferred approach for pulley-cutting procedure.* ***(Right)*** *Clinical photo shows the transverse oblique palmar approach for annular pulley injection to treat stenosing tenosynovitis ("trigger finger").*

Trigger Finger Injection

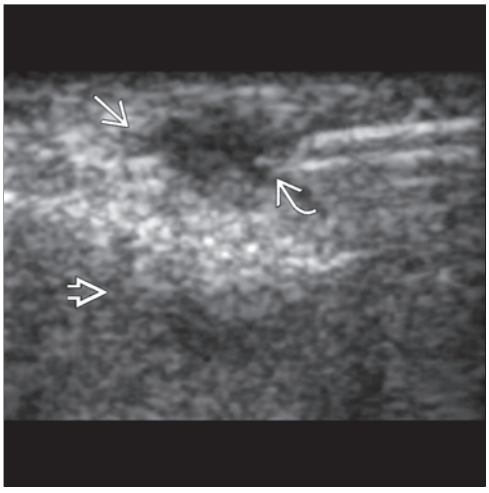


Tenosynovitis Aspiration

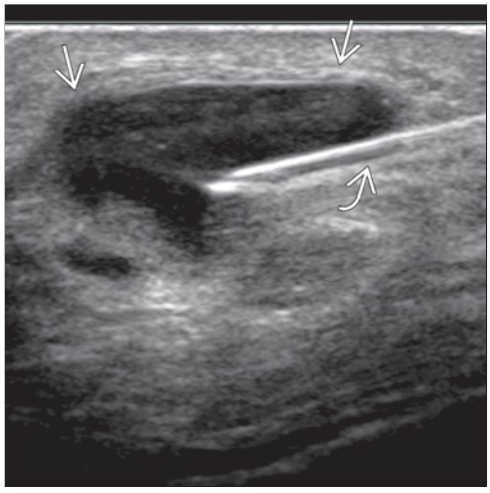


(Left) *Longitudinal ultrasound shows steroid (10 mg methylprednisolone) injection to treat trigger finger. A 23-g needle is placed within the tendon sheath just deep to the mildly thickened A1 pulley.* ***(Right)*** *Transverse ultrasound shows mild, possibly infective, flexor tenosynovitis of the index finger overlying the proximal phalanx. Fluid from the small tendon sheath effusion was aspirated using a 21-g needle for culture. Fluid culture was sterile.*

Ganglion Aspiration



Ganglion Aspiration

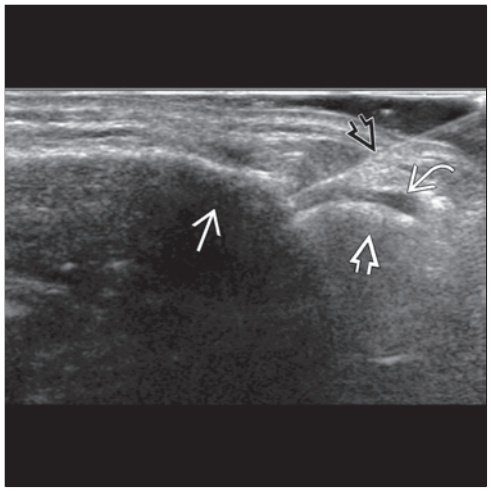


(Left) *Transverse ultrasound of the dorsal wrist shows a small ganglion superficial to the scaphoid. A 21-g needle is inserted into this ganglion via a dorsal approach. The needle tip lies within the ganglion.* ***(Right)*** *Oblique ultrasound of the palm shows a large ganglion within the thenar muscle. A 21-g needle is inserted via a palmar approach. The needle tip lies within the ganglion.*

Radiocarpal Joint Injection

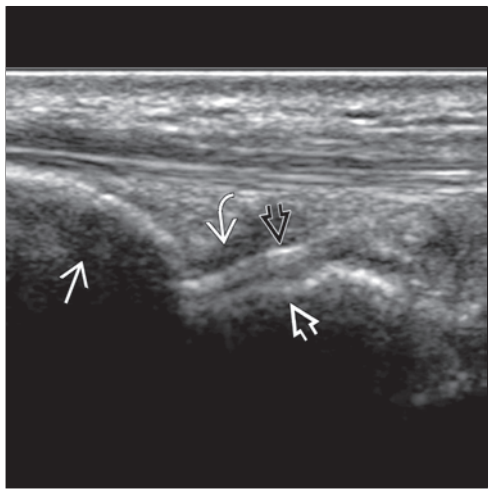


Radiocarpal Joint Injection

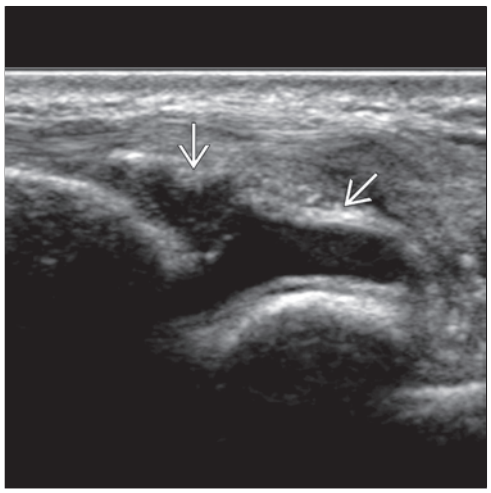


(Left) *Clinical photo shows a longitudinal dorsal approach for injection of the radiocarpal articulation.* ***(Right)*** *Longitudinal ultrasound shows ultrasound-guided contrast injection of the the radiocarpal articulation. A 25-g spinal needle lies within the joint space between the distal radius and the scaphoid. A small amount of contrast has been injected into the joint.*

Radiocarpal Joint Injection

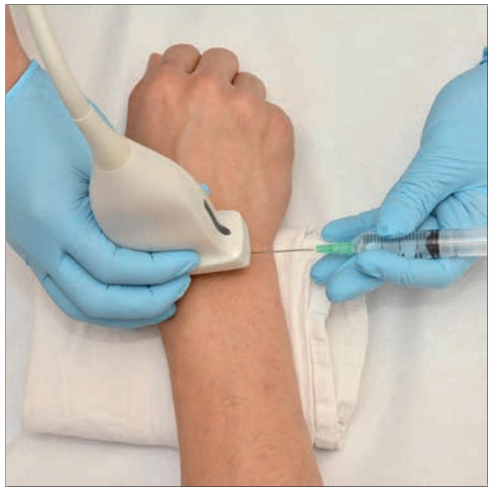


Radiocarpal Joint Injection

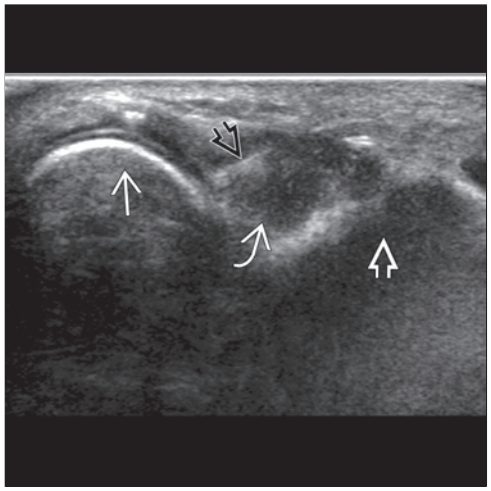


(Left) *Longitudinal ultrasound shows ultrasound-guided contrast injection into the radiocarpal articulation for MR arthrography. A 25-g spinal needle lies within the joint space between the distal radius and the scaphoid. A small amount of contrast has been injected into the joint.* ***(Right)*** *Longitudinal ultrasound of the same patient shows distension of the radiocarpal articulation after the injection has been completed.*

Distal Radioulnar Joint Injection

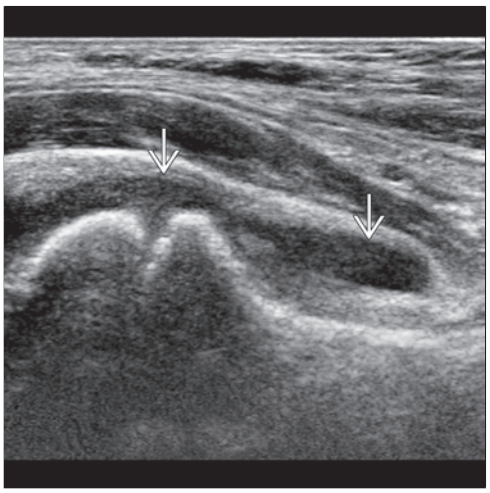


Distal Radioulnar Joint Injection

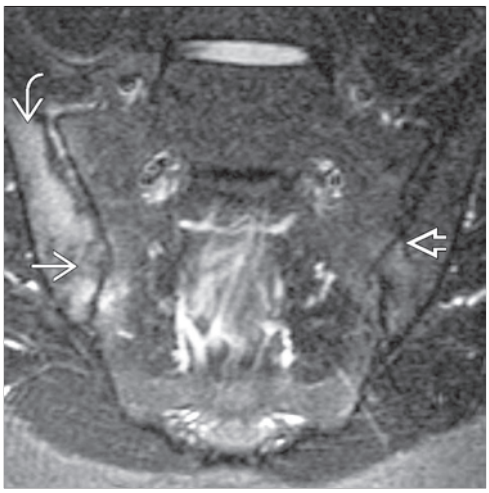


(Left) *Clinical photo shows the transverse dorsal approach for injection of the distal radioulnar articulation.* ***(Right)*** *Axial ultrasound shows ultrasound-guided contrast injection for MR arthrography into the distal radioulnar articulation. A 25-g spinal needle lies within the joint space between the distal ulna and the distal radius. A small amount of contrast has been injected into the joint.*

HIP AND PELVIS PROCEDURES



Longitudinal US of child shows a medium-sized hip effusion ➔ due to transient synovitis with similar though less severe changes in the opposite hip (not shown). Joint aspiration is indicated if infection is clinically suspected.



Coronal oblique T2 FS MR shows a right-sided sacroiliitis with joint irregularity ➔ & bone marrow edema ➔ (left SI joint normal ➔). Steroid & local anesthetic injection is indicated for inflammatory sacroiliitis.

PRE-PROCEDURE

Indications

- Aspiration or drainage of hip joint fluid
  - Suspected septic arthritis or crystal arthropathy
- Hip or sacroiliac (SI) injection of contrast medium or medication
  - Hip arthrography (conventional, CT, or MR) for chondral injury or labral tear
  - Ultrasound-CT/MR fusion imaging particularly useful for SI joint injection
- Medication for relief of pain or inflammation
  - Hip or sacroiliac joint injection
  - Steroid, hyaluronic acid injection for painful osteoarthritis or inflammatory arthritis
  - Radiosynovectomy (e.g., Yttrium-90, half-life 2.7 days) for chronic synovitis such as hemophiliac arthropathy or inflammatory joint disease
- Paraarticular tendon injection
  - Tendinosis & partial tears of gluteus medius & minimus, adductor & psoas tendons
  - Steroid and long-acting local anesthetic injection
  - Also consider dry needling, autologous blood injection, platelet-rich plasma (PRP) injection to stimulate healing response
    - Not as widely used in pelvis/hip tendons as in Achilles, patellar, or elbow tendons
- Paraarticular cyst or bursal aspiration
  - Symptomatic or large paralabral cyst or paraarticular ganglion cyst may benefit from aspiration
  - Paralabral or ganglion cysts are more common with hip arthropathy but can occur with isolated acetabular labral tear
  - Bursae common around greater trochanter and psoas tendon though most clinical "trochanteric bursitis" is due to gluteus medius/minimus tendinosis with peritendinitis rather than bursitis
    - Nondistended hip bursae are not visible on ultrasound
- Biopsy of synovial tissue for infection, inflammation, or synovial tumor
- Iliolumbar ligament injection for relief of pain

Getting Started

- Things to check
  - Time-out procedure (patient identity, type & side of procedure)
  - Discuss risk of infection, allergy, bleeding, neurovascular injury, and (if necessary) tendon rupture
  - Ensure consent form signed
  - Sedation rarely required
- Medications
  - Local anesthetic for skin: 2-3 mL, 1% lignocaine (optional)
  - Local anesthetic for joint injection: 1% or 2% lignocaine, or 0.25-0.5% bupivacaine (Marcaine)
  - Steroid: 40 mg/mL methylprednisolone (Depo-Medrol)
  - Hyaluronic acid (viscosupplementation)
    - Macromolecule occurring naturally in synovial fluid and contributing to its viscoelastic property
    - Produced by synoviocytes, fibroblasts, and chondrocytes
    - Concentration and molecular weight of hyaluronic acid is reduced in osteoarthritis
  - Contrast
    - CT arthrogram: 10 mL iodinated contrast (Omnipaque 300 mg/dL ± 0.1 mL of 1:1,000 epinephrine)
    - MR arthrogram: 10 mL diluted gadolinium solution (0.1 mL gadolinium in 10 mL normal saline solution)
- Equipment list
  - Sterile set for injection or aspiration
  - Spinal needle 18- to 22-g (3.5'') depending upon type of procedure and viscosity of fluid if aspiration undertaken
    - If viscous aspirate expected, use larger bore needle (e.g., 16- or 18-g)
  - Extension tube, 250 mm 8.5F, 0.4 mL dead space
  - Syringes for local anesthetic, injection, & aspiration
  - Coaxial needle & biopsy needle

Key Facts

Pre-Procedure

- Aspiration or drainage of hip joint fluid
- Hip or sacroiliac joint injection (medication or contrast medium)
- Paraarticular tendon injection (gluteus medius, minimus, and adductor tendons)
- Paraarticular cyst or bursal aspiration
- Biopsy of synovial tissue for infection, inflammation, or synovial tumor

Procedure

- Ultrasound-guided joint injection as effective as and quicker than fluoroscopic-guided joint injection
  - Depending on body habitus, use either 5-10 MHz linear array transducer (smaller patients) or 3-5 curved array transducer (larger patients)
- For hip, anterior longitudinal approach usually used, either targeting femoral head or femoral neck
  - Avoid femoral neurovascular bundle
- For sacroiliac joint injection, patent lies prone with joint identified at level of S1 & S2 foramina
- Treatment of paraarticular tendinosis ± tendon tears
  - Common indication for pelvic/hip intervention
  - Steroid and long-acting local anesthetic
  - Autologous blood injection or platelet-rich plasma injection less frequently used
- Paraarticular cyst or bursal aspiration
  - 21-g needle for cyst aspiration or > 19-g needle for more viscous content
  - ± hyaluronidase pre aspiration ± steroid post aspiration

- Sterile bottles, specimen bottles

PROCEDURE

Procedure Steps

- Aspiration of joint fluid or injection of medication or contrast medium
  - Ultrasound-guided joint injection is as effective as and quicker than fluoroscopic-guided joint injection
  - **Hip joint injection**
    - Patient lies supine with hip in neutral alignment ± pillow beneath knee to relax anterior part of hip capsule
    - Choose puncture site away from femoral neurovascular bundle
    - Anterior longitudinal approach usually used, targeting either femoral head or femoral neck
      - Capsule less thick at femoral head area and not covered by synovial reflection
      - Target point for femoral head is superolateral quadrant of femoral head
      - Capsule at neck region thickened by zona orbicularis (circular fibers of capsule that blend with deeper fibers of iliofemoral ligament)
      - Target point for femoral neck is femoral head-neck junction
    - Depending on body habitus, use either 5-10 MHz linear-array transducer (smaller patient) or 3-5 MHz curved-array transducer (larger patient)
    - Align transducer parallel to femoral neck
    - Use 22-g spinal needle & free-hand technique under real-time ultrasound guidance
      - Insert needle until bony contour of proximal femur is contacted; may feel distinct pop as capsule is punctured
      - Relax downward pressure on needle and start injection turning bevel until free flow of injectate occurs from needle tip
      - Needle tip embedded in reflected synovium at femoral neck may impede fluid flow, so may need to withdraw needle a tiny fraction into anterior synovial recess
    - For osteoarthritis, inject 1 mg (40 mg) triamcinolone & 4 mL 0.5% bupivacaine
  - **SI joint injection**
    - Patient lies prone, and 5-7.5 MHz linear or curved array transducer is used
    - Posterosuperior aspect of SI joint is fibrous, whereas anteroinferior aspect of SI joint is synovial
      - Distal end of SI joint is slightly easier to see and access than proximal end of SI joint
      - Nevertheless, both proximal or distal ends can be successfully cannulated in most patients
    - Proximal end of SI joint lies at level of S1 foramen
      - With transducer transverse, first identify posterior superior iliac spine laterally and transverse process L5 medially
      - Move transducer caudally, depicting medial and lateral sacral crests
      - At level of S1 foramen, hypoechoic cleft laterally represents SI joint
    - Distal end of SI joint lies at level of S2 foramen
      - Move transducer caudally in transverse plane until S2 foramen visualized
      - At level of S2 foramen, hypoechoic cleft laterally represents SI joint
    - Use 21-g spinal needle (9 cm)
      - Needle orientation almost vertical and same orientation as hypoechoic SI joint cleft
      - Paraxial transducer approach for initial skin puncture
      - Then longitudinal position used to guide needle toward SI joint
      - Switch back to paraxial transducer position when needle tip reaches entrance to SI joint
      - Concentrate on contacting hypoechoic cleft of SI joint & avoiding bony spurs
      - Once SI joint contacted, needle can be inserted for about 1 cm further into joint
      - Inject 1 mg (40 mg) triamcinolone & 0.5 mL 2% bupivacaine
- **Treatment of paraarticular tendinosis & tears**
  - Commonest indication for pelvic/hip ultrasound-guided intervention
    - Gluteus medius tendinosis more common (2-3x) than gluteus minimus tendinosis and particularly common in middle-aged females

    - Adductor tendinosis less common whereas psoas tendinosis is uncommon
  - Patient lies in decubitus position with affected side upright for gluteal tendons or with hip flexed and adducted for adductor tendons and psoas tendon
    - Probe positioned over area of tendinosis
  - Inject total of 1 mL 30-40 mg/mL methylprednisolone or triamcinolone mixed with 8mL (0.5%) bupivacaine
    - For gluteal tendons, longitudinal approach going from inferior to superior
      - Initially inject deep to gluteus medius tendon (submedius bursa)
      - Then withdraw needle and inject just superficial to tendon (trochanteric bursa)
      - Adjust needle until there is free flow of injectate away from needle tip
      - Large volume (8 mL) of bupivacaine may help dispersion of steroid around affected area
      - Steroid treats peritendinitis ± bursitis associated with tendinosis rather than tendinosis per se
      - Similar procedure for gluteus minimus tendon
    - Steroid injection can only be repeated once or twice after several weeks
    - Good short-term but poor long-term clinical effect
  - Autologous blood injection or PRP injection not widely performed for tendons around hip
    - For ABI: Up to 5 mL blood withdrawn from arm vein and injected directly into tendon substance
      - Blood and platelets are a rich source of factors for tendon healing
    - For PRP: Larger amount of blood (20-60 mL) withdrawn from arm vein & centrifuged for 15 min to separate platelets from other cells
      - Anticoagulant added to prevent premature platelet activation
      - PRP injection reported as useful for adductor tendinosis
      - Significant improvement in symptoms at 6 weeks and for up to 2 years following injection
- Paraarticular labral/ganglion cyst or bursal aspiration
  - 21-g needle for cyst aspiration or > 19-g needle for more viscous content
  - ± hyaluronidase (150 U in 2 mL saline) pre aspiration
    - Hyaluronidase is an enzyme that degrades hyaluronic acid in paralabral or ganglion cyst
    - Inject hyaluronidase into cyst; leave needle tip within cyst for 15 minutes and then aspirate
  - ± steroid (1 mL 30-40 mg/mL methylprednisolone or triamcinolone) post aspiration

Findings and Reporting

- Depends on interventional procedure performed, but one should consider reporting on these aspects
  - Initial ultrasound findings
    - Do not do any interventional procedure without first doing full assessment of ultrasound findings
  - Immediate complication, e.g., excessive bleeding
  - Specific patient aftercare
  - Type and size of needle used
  - Amount and type of local anesthetic used
  - Volume, color, and viscosity of joint fluid aspirated
  - If biopsy undertaken, record if only friable material obtained

POST-PROCEDURE

Expected Outcome

- Mild discomfort 1-2 days after contrast or medication injection or cyst aspiration

Immediate Aftercare

- Send any aspirate for microbiology, cytology, crystal analysis (need fresh specimen) as appropriate
- Perform MR, CT, or conventional arthrography within 30 minutes of contrast injection, as contrast will absorb

Subsequent Aftercare

- Avoid exercise for 24 hours after steroid injection to maximize therapeutic effect & reduce spread of steroid into surrounding tissues
- After specific tendon therapy other than steroid injection, refrain from tendon loading activity for 2 weeks following procedure with no return to sporting activity/training for 6 weeks

OUTCOMES

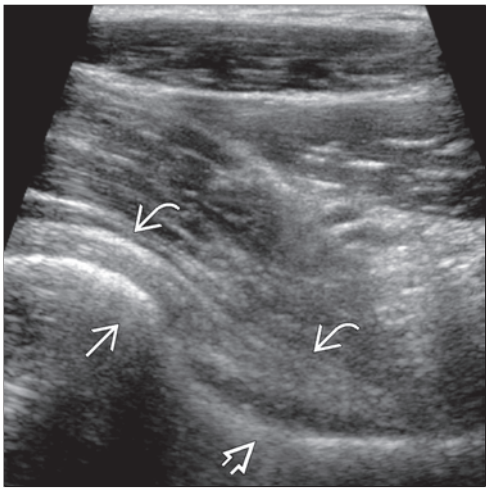
Complications

- Most feared complication(s)
  - Infection, e.g., septic arthritis
    - Avoid traversing infected tissues between skin & joint
  - Extravasation of contrast/medication
    - Steroid or radiosynovectomy agent: Fat pad atrophy, skin atrophy, skin depigmentation
- Immediate/periprocedural complication(s)
  - Neurovascular injury, particularly femoral nerve paraesthesia after hip joint injection (2%)
    - Femoral nerve lies just lateral to artery (NAVeL, **n**erve, **a**rtery, **v**ein, **l**ymph nodes)
  - Bleeding: Especially in bleeding diathesis e.g., hemophiliac arthropathy treated with radiosynovectomy
  - Capsular rupture
  - Allergic reaction
- Delayed complication(s)
  - Pain for 1-2 days after steroid injection due to steroid-related microcrystalline synovitis
    - Will settle with oral analgesia
  - Following ganglion or paralabral cyst aspiration, leakage of cyst contents through puncture site into surrounding soft tissues can induce a chemical cellulitis lasting ~ 48 hours
    - Will settle with oral analgesia

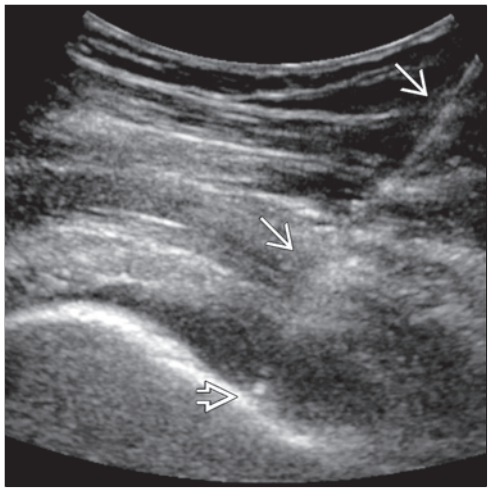
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2. Zacchino M et al: Use of ultrasound-magnetic resonance image fusion to guide sacroiliac joint injections: a preliminary assessment. J Ultrasound. 16(3):111-8, 2013
3. Klauser A et al: Feasibility of ultrasound-guided sacroiliac joint injection considering sonoanatomic landmarks at two different levels in cadavers and patients. Arthritis Rheum. 59(11):1618-24, 2008

Hip Ultrasound

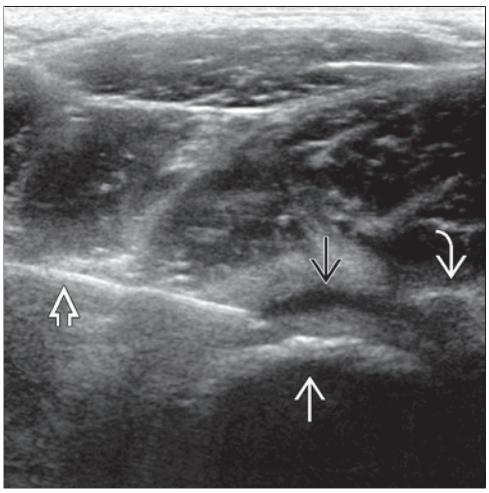


Hip Joint Injection

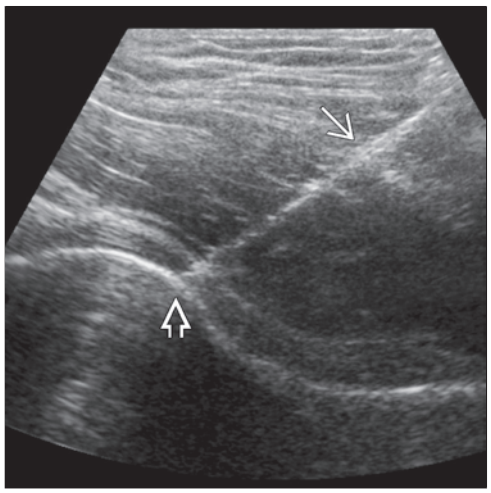


(Left) *Longitudinal oblique ultrasound shows normal contour of femoral head and neck with hip capsule. The capsule is attached to the acetabular rim and the intertrochanteric area. There is a synovial reflection, not seen on ultrasound, along the femoral neck.* ***(Right)*** *Longitudinal oblique ultrasound shows position of a 22-g spinal needle during contrast injection for hip MR arthropathy. The needle tip contacts the head-neck junction, which is flattened in this patient with femoroacetabular impingement.*

Hip Joint Injection

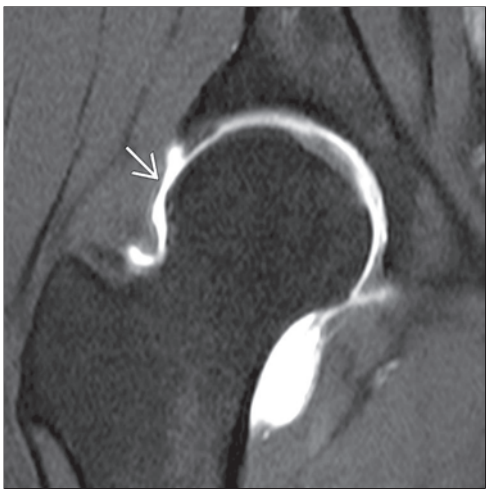


Hip Joint Injection

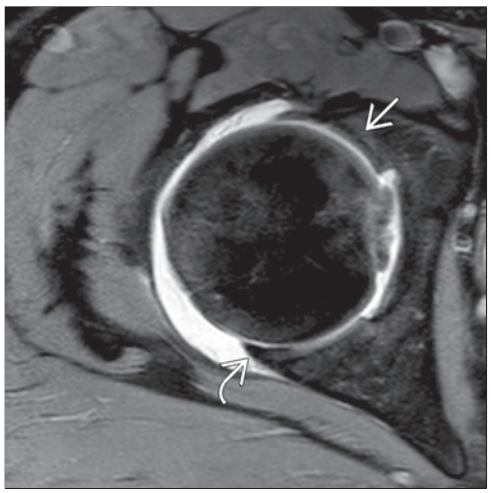


(Left) *Longitudinal oblique ultrasound shows an 18-g spinal needle inserted longitudinally from lateral to medial along the line of the femoral neck. The needle tip lies in the partially distended hip joint. Part of the femoral neck and the acetabulum are seen.* ***(Right)*** *Longitudinal oblique ultrasound shows the position of a 22-g spinal needle for contrast injection prior to hip MR arthropathy. The needle tip contacts the superolateral aspect of the femoral head.*

MR Arthrography of Hip



MR Arthrography of Hip



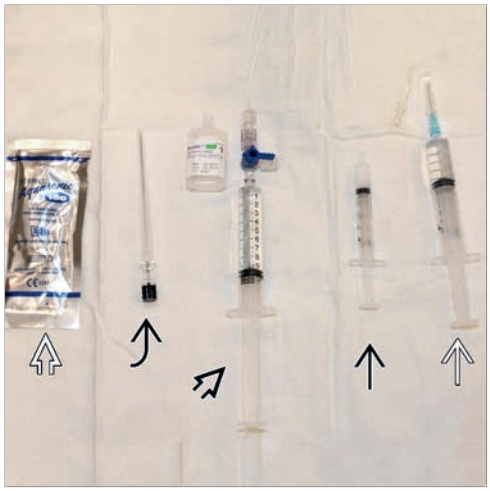
(Left) *Coronal oblique T1WI FS MR shows distended hip capsule following ultrasound-guided injection of 10 mL of contrast medium/normal saline mixture. Note the zona orbicularis (from circular fibers of the hip capsule), which needs to be traversed when the femoral neck is targeted for ultrasound-guided hip injection.* ***(Right)*** *Axial T1WI FS MR arthrography shows the normal acetabular labrum and the articular cartilage. MR arthrography is particularly useful for detecting chondral defects.*

HIP AND PELVIS PROCEDURES

Steroid Injection

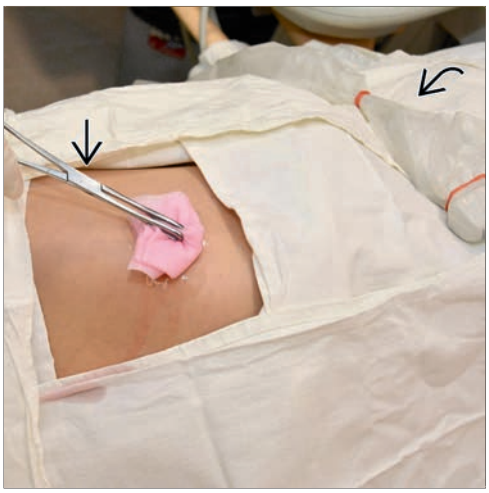


Setup for Hip Joint Injection



(Left) *Photograph shows steroid injection preparation prior to either periarticular or articular injection. Typical injection would be 1 mL (40 mg) of triamcinolone, usually mixed with 2-4 mL 0.5% bupivacaine (long-acting local anesthetic).* ***(Right)*** *Photograph shows setup for articular or periarticular steroid and long-acting local anesthetic injection. Sterile ultrasound gel and a spinal needle (18- to 22-g, with larger needle for aspiration rather than injection) is used. Local anesthetic is applied to the skin.*

Site Preparation



Anesthetic Infiltration

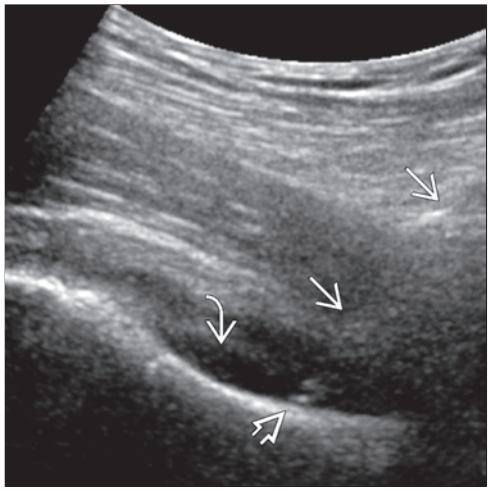


(Left) *Clinical photograph shows skin being cleaned with the injection site draped. Always clean from proposed skin entry site to more peripheral areas rather than vice versa. The ultrasound transducer is covered with a sterile probe cover.* ***(Right)*** *Clinical photograph in the same patient shows infiltration of local anesthetic to skin. One can also infiltrate anesthetic more deeply around the intended site of hip capsule puncture.*

Hip Joint Injection

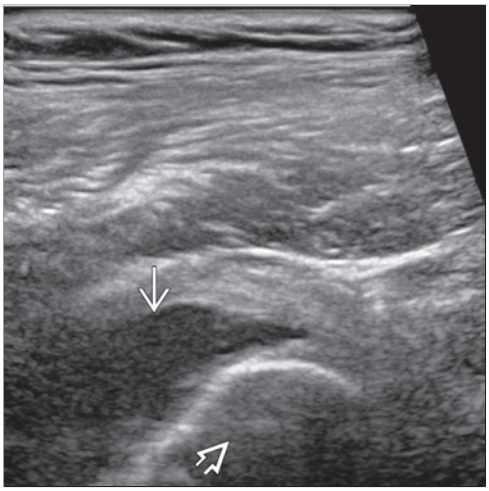


Hip Joint Injection

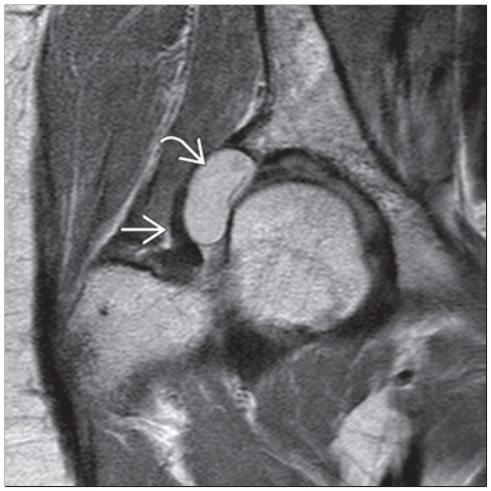


(Left) *Clinical photograph in the same patient shows a 22-g spinal needle being guided toward the hip joint under ultrasound guidance. Keep the advancing needle in view on ultrasound at all times.* ***(Right)*** *Longitudinal oblique ultrasound shows a faint needle track with the needle tip contacting the midpoint of the femoral neck. About 5 mL of contrast medium has been injected, resulting in mild distension of the hip capsule.*

Labral Cyst

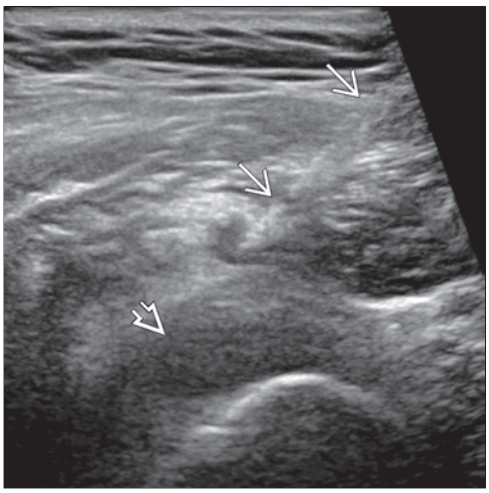


Labral Cyst

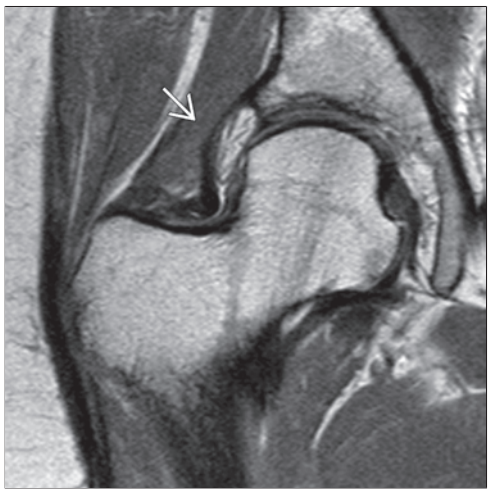


(Left) *Longitudinal ultrasound shows a quite large hypoechoic intracapsular labral cyst* ➔ *at the anterosuperior aspect of the hip joint in a patient with hip pain aggravated by abduction for 3 months. The femoral head* ➔ *is normal.* ***(Right)*** *Coronal oblique intermediate-weighted MR image in the same patient shows a large intracapsular labral cyst* ➔*. The cyst in this case lies deep to the hip capsule* ➔*. In view of troublesome symptoms, ultrasound-guided aspiration was arranged.*

Labral Cyst Aspiration

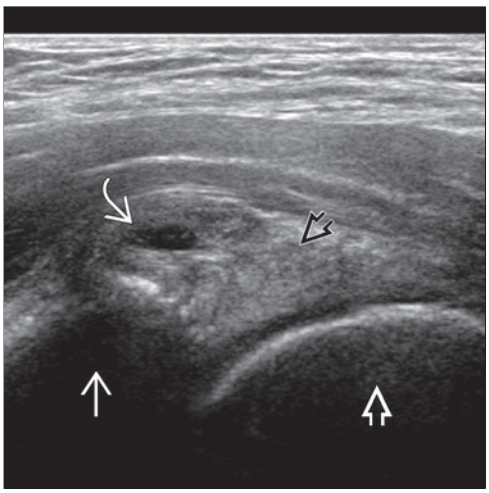


Post Labral Cyst Aspiration

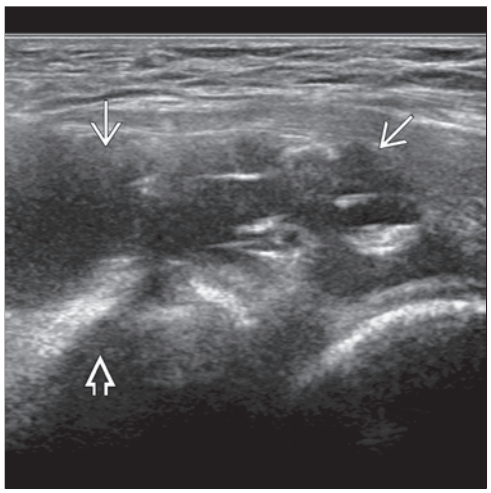


(Left) *Longitudinal ultrasound in the same patient shows an 18-g spinal needle* ➔ *approaching the labral cyst* ➔ *prior to cyst aspiration. Only 1 mL of thick gelatinous fluid could be aspired from the cyst.* ***(Right)*** *Coronal oblique PDWI MR in the same patient 2 weeks following ultrasound-guided labral cyst aspiration shows that the cyst* ➔ *has markedly reduced in size. Although only 1 mL of fluid could be aspirated from the cyst, it reduced to a greater degree as a result of postprocedure leakage of cyst content.*

Small Labral Cyst



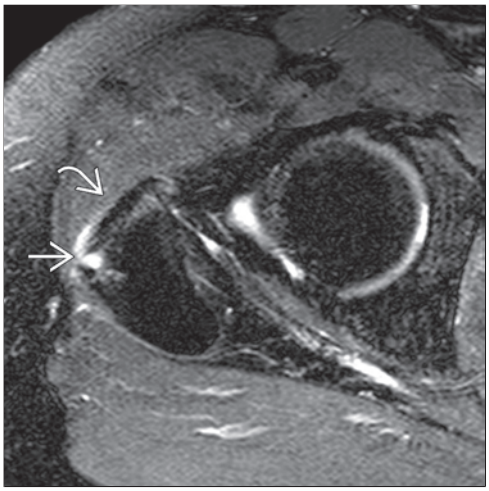
Large Paralabral Cyst

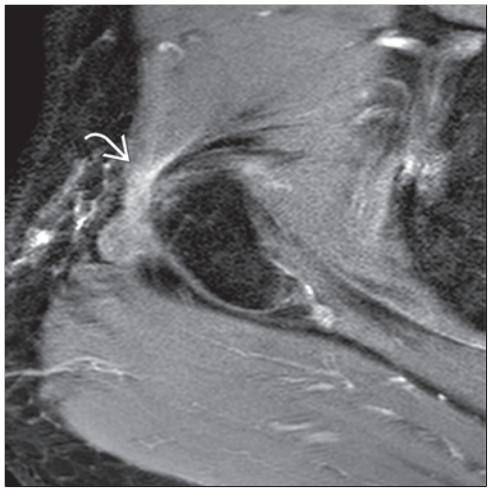


(Left) *Longitudinal oblique ultrasound shows a small labral cyst* ➔ *at the superior aspect of the acetabulum* ➔*. This small cyst is not likely to benefit from aspiration. There is marked thickening of the adjacent capsulolabral tissues* ➔ *along the superior aspect of the hip joint. The femoral head* ➔ *is normal.* ***(Right)*** *Longitudinal ultrasound shows a large irregular paralabral cyst* ➔ *extending superiorly alongside the acetabulum* ➔*. This poorly defined extracapsular paralabral cyst has undergone recent leakage.*

Gluteus Minimus Tendinosis and Tear

Gluteus Minimus Peritendinitis

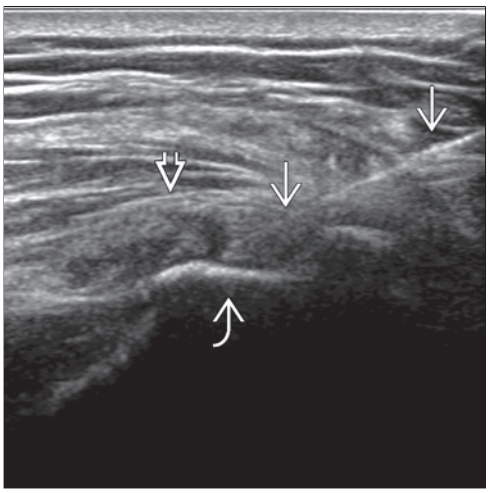


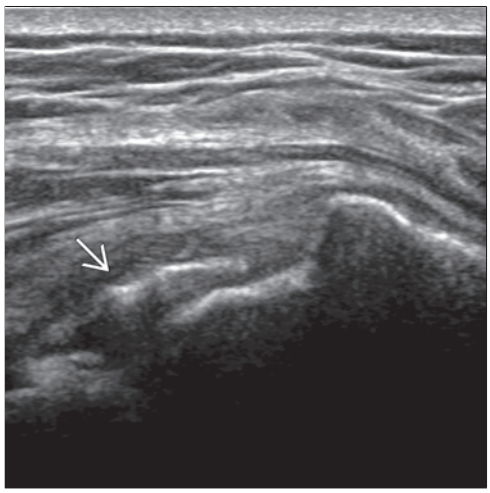


(Left) *Axial T2WI FS MR shows mild tendinosis of the gluteus minimus tendon near its insertion into the anterior facet of the greater trochanter. A small avulsive-type tear filled with fluid is also present more laterally. **(Right)** Axial T2WI FS MR of the same patient shows moderate peritendinitis with edema surrounding the gluteus minimus tendon just proximal to the insertional area. Peritendinitis is a common accompaniment of active tendinosis.*

Gluteus Minimus Tendon Injection

Gluteus Minimus Tendon Injection

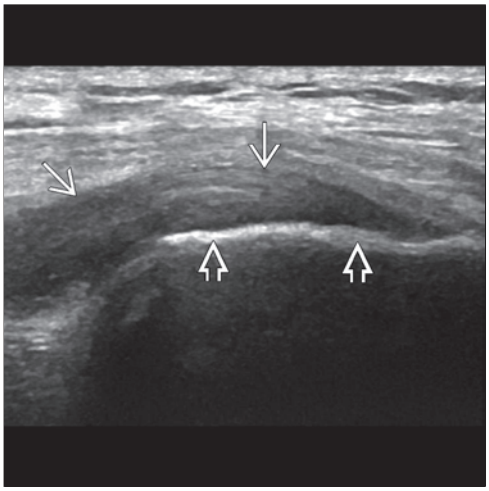


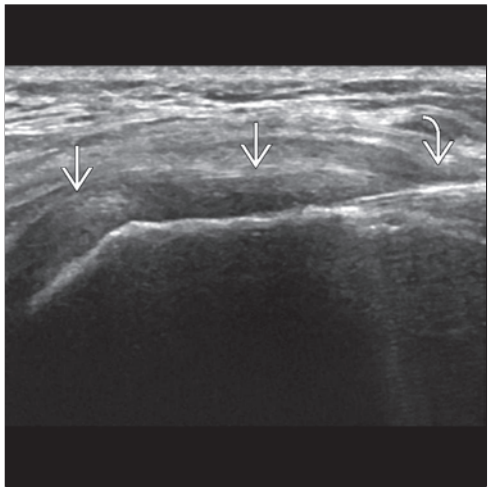


(Left) *Transverse ultrasound shows moderate gluteus minimus tendinosis with thickening and hypoechogenicity at the greater trochanteric insertional area. A 20-g spinal needle has been inserted deep to the tendon for steroid (1 mL triamcinolone 40 mg) and long-acting local anesthetic (1 mL 0.5% bupivacaine) injection. **(Right)** Transverse ultrasound in the same patient shows echogenic air loculus at the injection site immediately following needle removal.*

Gluteus Medius Tendinosis

Gluteus Medius Tendon Injection



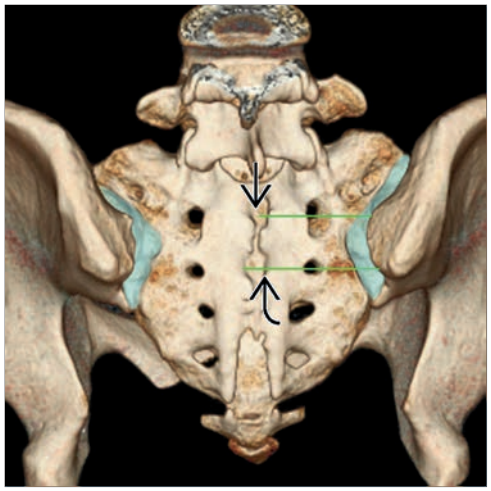


(Left) *Transverse ultrasound shows moderate severity gluteus medius tendinosis with thickening and hypoechogenicity of the tendon near the insertional area into the lateral and superoposterior facets of the greater trochanter. No tendon tear is evident. **(Right)** Transverse ultrasound in the same patient shows a 20-g spinal needle inserted deep to the peripheral part of the gluteus medius tendon prior to injection of steroid (1 mL triamcinolone 40 mg) and long-acting local anesthetic (1 mL 0.5% bupivacaine).*

Sacroiliitis

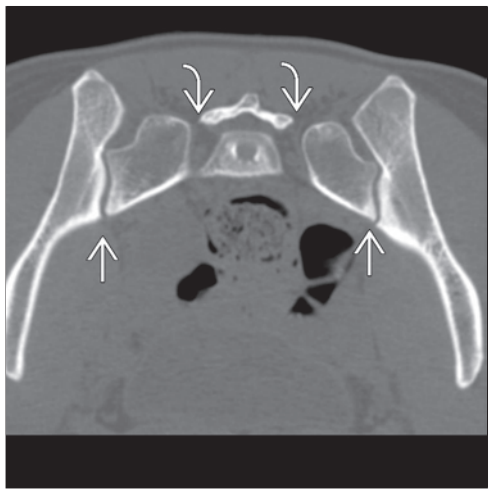


3D CT of Sacrum



(Left) *Frontal radiograph shows moderate-severity bilateral sacroiliitis. Ultrasound-guided steroid and long-acting local anesthetic injection is a useful treatment for inflammatory sacroiliitis.* ***(Right)*** *Coronal 3D CT of sacrum shows regions of sacroiliac joints (shaded green). The proximal end of the sacroiliac joint is level with the S1 foramen. The distal end of the sacroiliac joint is level with the S2 foramen.*

Upper Aspect of Sacroiliac Joint

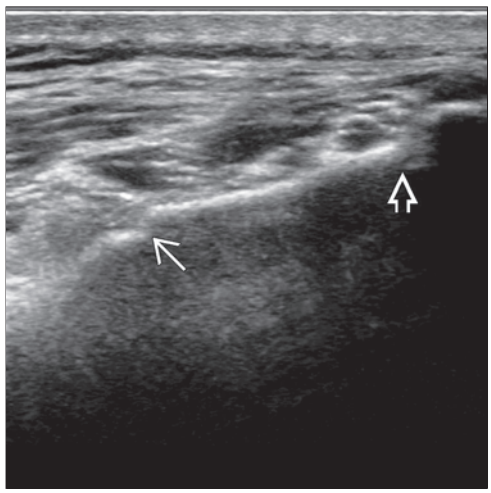


Lower Aspect of Sacroiliac Joint

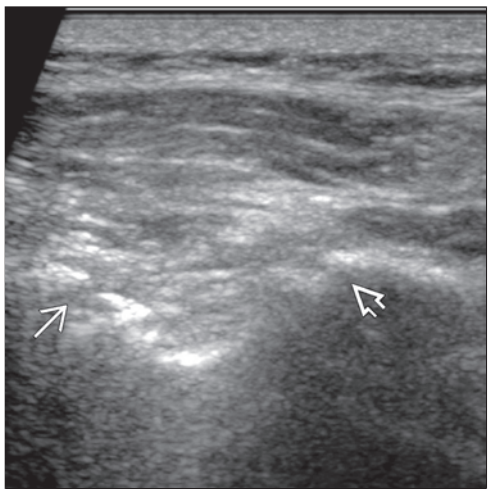


(Left) *Transverse CT shows proximal end of sacroiliac joints at the level of the 1st sacral foramen. Note the lateral needle angulation required to enter the dorsal aspect of the sacroiliac joints.* ***(Right)*** *Transverse CT shows distal end of sacroiliac joints at the level of the 2nd sacral foramen. Note the lateral needle angulation required to enter the dorsal aspect of the sacroiliac joint. Either CT or ultrasound or ultrasound-CT/MR fusion imaging can be used for needle insertion to the sacroiliac joint.*

Proximal Part Sacroiliac Joint

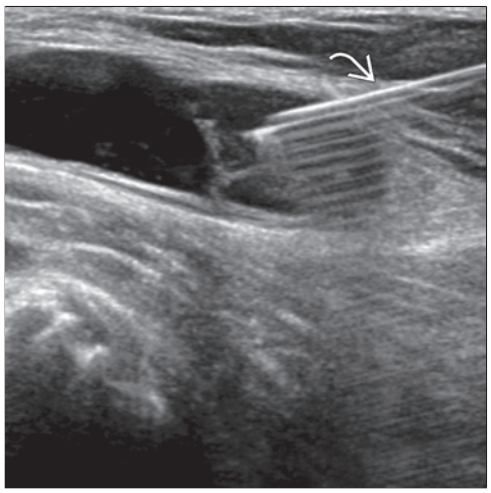


Distal Part Sacroiliac Joint

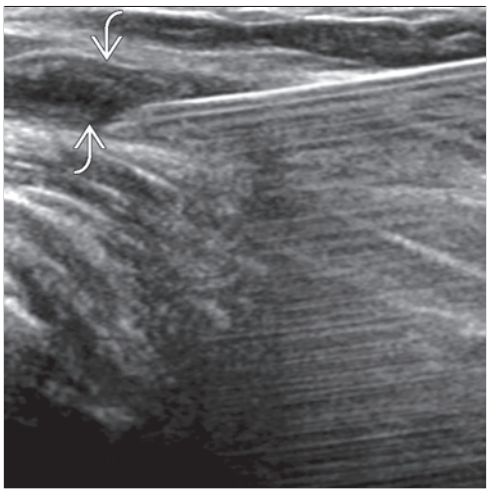


(Left) *Transverse ultrasound shows the normal proximal part of the left sacroiliac joint. The S1 neural foramen centrally and the sacroiliac joint peripherally are shown.* ***(Right)*** *Transverse ultrasound shows the normal distal part of the left sacroiliac joint. The S2 neural foramen centrally and the sacroiliac joint peripherally are shown. The lower part of the sacroiliac joint is generally slightly easier to access with ultrasound guidance than the upper part of the sacroiliac joint.*

KNEE PROCEDURES



Longitudinal ultrasound shows a Baker cyst prior to aspiration using a 18-g spinal needle. It is not possible to predict the viscosity of periarticular knee cysts based on ultrasound appearances.



Longitudinal ultrasound of the same Baker cyst following aspiration shows almost complete collapse of the cyst. The bursal wall can still be appreciated.

PRE-PROCEDURE

Indications

- Intraarticular aspiration or drainage of joint fluid
  - Suspected septic arthritis or crystal arthropathy
- Intraarticular injection of contrast medium or medication
  - Arthrography (conventional, CT, or MR)
    - Stability of osteochondral lesion
    - Evaluation of postoperative meniscus
  - Medication for relief of pain or inflammation
    - Steroid or hyaluronic acid injection for painful inflammatory osteoarthritis or inflammatory arthritis
  - Radiosynovectomy for chronic synovitis such as hemophiliac arthropathy and inflammatory arthritis
    - Reduces frequency of recurrent clinical and subclinical hemarthroses in patients with hemophilia
    - Decreases intensity of pain and degree of synovial proliferation
    - Satisfactory clinical response (85%) in large joint monoarthropathy
- Paraarticular aspiration
  - Symptomatic or large Baker cyst or parameniscal cyst
    - Baker cyst is usually due to knee arthropathy and tense knee effusion
      - Reducing size of effusion by intraarticular aspiration can reduce size of Baker cyst
    - Parameniscal cyst is usually due to horizontal meniscal tear
      - Often treated intraarticularly by partial meniscectomy
    - If large, both Baker cyst and parameniscal cyst can be treated percutaneously
- Paraarticular tendon injection
  - Patellar/semimembranous/quadriceps/pes anserinus tendinosis injection to stimulate healing response
  - Dry needling, steroid injection, prolotherapy, autologous blood injection (ABI), platelet-rich plasma (PRP) injection
- Biopsy of synovial tissue for suspected infection, inflammation, or synovial tumor

Getting Started

- Things to check
  - Time-out procedure (patient identity, type and side of procedure)
  - Discuss risk of infection, allergy, bleeding, and if necessary, tendon rupture
  - Informed consent form signed
  - Sedation rarely required
- Medications
  - Local anesthetic for skin: 2-3 mL, 1% lignocaine
  - Local anesthetic for intraarticular injection: 1% or 2% lignocaine or 0.25-0.5% bupivacaine (Marcaine)
  - Steroid: 40 mg/mL methylprednisolone (Depo-Medrol)
  - Hyaluronic acid ("viscosupplementation")
    - Macromolecule occurring naturally in synovial fluid and contributing to its viscoelastic property
    - Produced by synoviocytes, fibroblasts, and chondrocytes
    - Concentration and molecular weight of hyaluronic acid is reduced in osteoarthritis
  - Contrast
    - CT arthrogram: 40 mL iodinated contrast (iohexol [Omnipaque] 300 mg/dL ± 0.1 mL of 1:1000 epinephrine)
    - MR arthrogram: 40 mL diluted gadolinium solution (0.1 mL gadolinium in 10 mL normal saline solution)
- Sterile set for injection or aspiration
- Spinal needle 18- to 22-g
  - Depending on type of procedure and viscosity of fluid if aspiration undertaken
- Extension tube, 250 mm, 8.5 Fr, 0.4 mL dead space
- Syringes for local anesthetics (LA), aspiration, and injection
- Coaxial needle and biopsy needle
- Sterile bottles, specimen bottles

KNEE PROCEDURES

Key Facts

Pre-Procedure

- **Indication**
- Intraarticular aspiration of joint fluid or injection of contrast medium or medication
- Paraarticular tendinosis or ligament tear treatment
  - Dry needling, steroid injection, prolotherapy, autologous blood injection, platelet-rich plasma injection
- Paraarticular cyst or bursal aspiration
  - Symptomatic Baker cyst or ganglion cyst aspiration
  - Parameniscal cyst: Voluminous & painful cysts may benefit from aspiration/injection
  - ≥ 19-g needed for more viscous content
- Biopsy of synovial tissue/intraarticular soft tissue mass

Procedure

- Intraarticular aspiration/drainage of joint fluid or injection
  - Lateral, medial, or suprapatellar recess
  - Steroid or hyaluronic acid
- Paraarticular tendinosis or ligament treatment
  - Identify most severe area of tendinosis, as this will benefit most from percutaneous intervention
  - Dry needling
  - Peritendinous steroid injection: Good short-term but limited long-term benefit
  - Prolotherapy: Reduces pain severity & area of visible tendinosis on ultrasound
  - Autologous blood or platelet-rich plasma injection provides best clinical outcome

PROCEDURE

Procedure Steps

- **Intraarticular aspiration of joint fluid or injection of medication or contrast medium**
  - Can aspirate either medial or lateral patellar recess or suprapatellar recess
    - Patient lying supine, knee flexed slightly
    - Place small pillow behind knee
    - For suprapatellar pouch, probe is placed in sagittal plane superior to patella, with distal quadriceps tendon seen in long axis
    - Keep probe parallel to quadriceps tendon but move it medially or laterally until quadriceps fibers are out of view
    - Flush needle and tubing with injectate beforehand to avoid bubbles being injected
    - Using free-hand technique, advance needle (19- to 23-g) into joint space under real-time imaging
    - If needle tip not seen, move needle slightly in and out to help confirm needle tip position
    - Free flow of fluid during aspiration or injection confirms intraarticular position of needle tip
  - Aspirate as much as possible for decompression
    - If effusion is too thick, consider changing to larger bore needle, e.g., 16- or 18-g
    - If insufficient aspirate, rotate 180° to change position of bevel or slightly retract and reposition needle tip
      - Probe pressure can displace fluid away from needle
      - Use free hand to massage joint fluid toward needle tip under real-time imaging
    - If still insufficient for sampling, irrigate joint with saline solution, then aspirate saline wash and label as joint wash
    - If repeated irrigation required, consider insertion of drainage catheter
- **Paraarticular aspiration**
  - For Baker cyst
    - Prone position; probe placed longitudinally along line of Baker cyst
  - For parameniscal cyst or ganglion cyst
    - Decubitus position: Probe placed longitudinally on cyst, anteroposterior approach with needle oriented sagittally
  - 21-g needle for cyst aspiration or > 19-g needle for more viscous content
  - ± hyaluronidase (150 units in 2 mL saline) prior to aspiration
    - Hyaluronidase: Enzyme that degrades hyaluronic acid
    - Inject into cyst, leave needle tip within cyst for 15 min, then aspirate
  - ± steroid (1 mL 30-40 mg/mL methylprednisolone or triamcinolone) post aspiration
- **Treatment of paraarticular tendinosis**
  - Probe positioned over area of tendinosis
  - Patient lies supine with knee slightly flexed to stretch quadriceps and patellar tendons during injection
    - External rotation of leg for pes anserinus tendons
    - Prone position for semimembranous tendon
  - Identify any discrete area of more severe tendinosis
    - As this is most likely to benefit from treatment
  - **Dry needling**
    - Infiltrate local anesthetic (3-5 mL 1-2% lignocaine) around tendon
    - Position needle tip within area of tendinosis
    - Move needle tip "to and fro" through tendinosis area for 1 minute
    - May undertake ABI or PRP injection following dry needling
  - **Peritendinous steroid injection**
    - 1 mL 30-40 mg/mL methylprednisolone or triamcinolone mixed with 1 mL (1%) lignocaine ± 1 mL (0.25%) bupivacaine
    - Aimed at peritendinous tissue alongside tendinosis area within patellar or quadriceps tendon
    - Usually can only be repeated once or twice after several weeks
    - Good short-term but poor long-term clinical effect
    - Helps to treat peritendinitis associated with tendinosis but no known effect on tendinosis per se
  - **Prolotherapy (or regenerative injection therapy)**
    - 1 mL 25% dextrose with lignocaine (1 mL 2% lignocaine [20 mg/mL] and 1 mL 50% dextrose [25 g/50 mL]) injected into tendinosis area

    - 4-6 prolotherapy treatment sessions required on average
      - More in severe cases and less in teenagers
    - Prolotherapy reduces pain and leads to reduction in degree of tendinosis on ultrasound
  - **ABI or PRP injection**
    - For ABI: Blood withdrawn from arm vein and injected directly into tendon
      - Amount of blood depends on size of tendon
      - 2-3 mL blood is injected for patellar tendon
    - For PRP: Larger amount of blood (usually 5-10 mL) is withdrawn from arm vein
      - Blood is placed into tube and centrifuged for 15 minutes
      - Separates platelets from white cells and red cells
      - Platelet-rich component is used for injection
    - Use Luer lock syringe for injection into tendon
      - Protects against explosive leakage from syringe because of back pressure during injection
      - Gentle controlled pressure and release technique on syringe plunger during injection will also help avoid syringe leakage
    - May require 2 interventions around 4-6 weeks apart
    - ABI or PRP reduce caliber of tendinosis area
    - Significant and lasting improvement in clinical symptoms and VISA (Victorian Institute of Sport Assessment) score
    - Accelerates recovery compared to exercise or dry needling therapy alone
      - For quadriceps tendon tear, PRP seems to hasten recovery period
- **Intraarticular soft tissue biopsy**
  - Use coaxial needle to prevent multiple skin punctures
  - For suspected malignant tumor, biopsy should be performed at site of subsequent surgery
  - For mobile intraarticular lesions, can be difficult to obtain a core as lesion may move away from needle tip during attempted cannulation
    - Fix lesion with free hand
    - If lesion in suprapatellar recess, flex knee to fix lesion by tightening surrounding structures

Findings and Reporting

- Depends on interventional procedure performed but consider reporting on these aspects
  - Initial ultrasound findings
    - Do not do any interventional procedure without first making full assessment of ultrasound findings and reporting clearly on these findings
  - Type and size of needle used
  - Amount and type of local anesthetic used
  - Volume, color, and viscosity of joint fluid aspirated
  - Record if friable biopsy material only obtained
- Immediate complication, e.g., excessive bleeding
- Specific patient aftercare

POST-PROCEDURE

Expected Outcome

- Mild discomfort due to reactive synovitis 1-2 days after contrast or medication injection

Immediate Aftercare

- Perform MR, CT, or conventional arthrography within 30 minutes of contrast injection as contrast will be absorbed
- Send aspirate for microbiology, cytology, crystal analysis (need fresh specimen) as appropriate

Subsequent Aftercare

- Avoid knee exercise for 24 hours after corticosteroid injection to maximize therapeutic effect and reduce spread of steroid into surrounding tissues
- After paraarticular soft tissue injection therapy, refrain from tendon-loading activity for a week following procedure
  - Avoid taking anti-inflammatory medication, which may theoretically impair healing process
- For tendon intervention
  - Rest for 2 weeks with no return to sporting activity/ training for 6 weeks

OUTCOMES

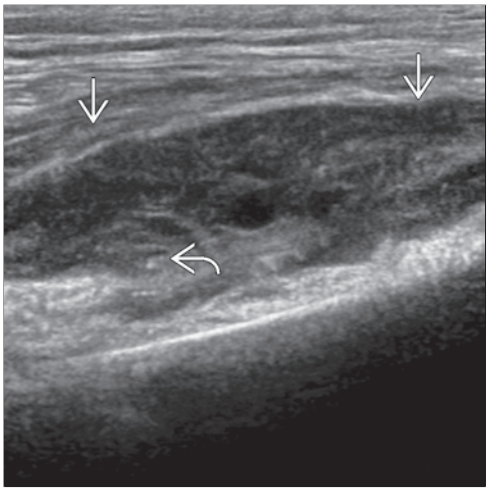
Complications

- Most feared complication(s)
  - Infection, e.g., septic arthritis
    - Avoid traversing infected tissues to the joint
  - Extravasation of contrast/medication
    - Steroid or radiosynovectomy agent: Fat pad atrophy, skin atrophy, skin depigmentation
- Immediate/periprocedural complication(s)
  - Bleeding: Especially in bleeding diathesis, e.g., hemophiliac arthropathy treated with radiosynovectomy
  - Capsular rupture
  - Allergic reaction
  - Neurovascular injury
- Pain 1-2 days after steroid injection due to steroid-related microcrystalline synovitis
  - Will settle with simple oral analgesia
- Following ganglion or parameniscal cyst aspiration, leakage of cyst contents through puncture site into surrounding soft tissues can induce a chemical-type cellulitis, which lasts for ~ 48 hours
  - Will improve with simple analgesia
- Patellar or quadriceps tendon rupture post PRP intervention

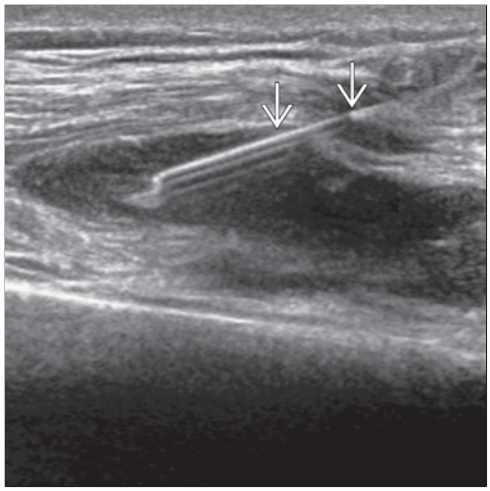
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1. Wong Y et al: Efficacy of yttrium-90 synovectomy across a spectrum of arthropathies in an era of improved disease modifying drugs and treatment protocols. Int J Rheum Dis. 17(1):78-83, 2014
2. Ferrero G et al: Ultrasound-guided injection of platelet-rich plasma in chronic Achilles and patellar tendinopathy. J Ultrasound. 15(4):260-6, 2012
3. Morvan G et al: Interventional musculoskeletal ultrasonography of the lower limb. Diagn Interv Imaging. 93(9):652-64, 2012

Ultrasound-Guided Aspiration

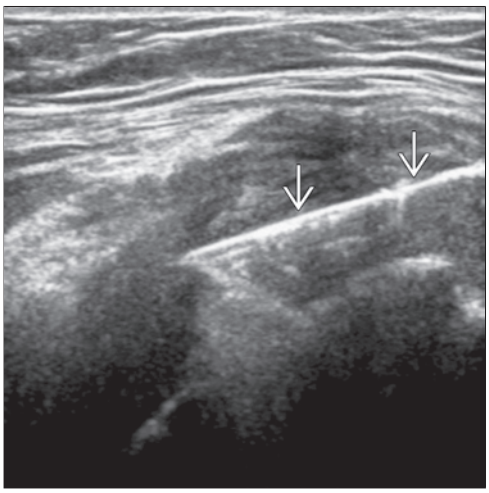


Ultrasound-Guided Aspiration

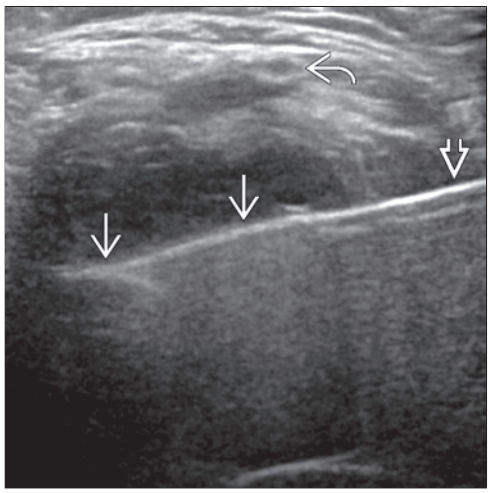


(Left) *Longitudinal ultrasound prior to ultrasound-guided aspiration of the lateral patellar recess shows severe synovial proliferation* ➔ *with some small echogenic foci* ➔. ***(Right)*** *Longitudinal ultrasound shows the same recess during aspiration using a 18-g spinal needle* ➔ *for culture and cytology. This revealed monosodium urate crystals consistent with gouty arthritis. No bacterial growth was obtained.*

Ultrasound-Guided Aspiration

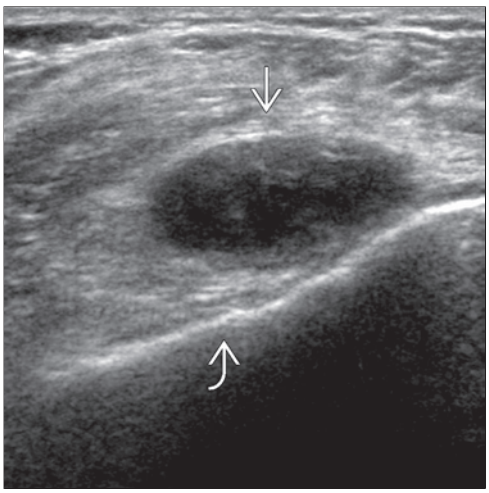


Ultrasound-Guided Biopsy

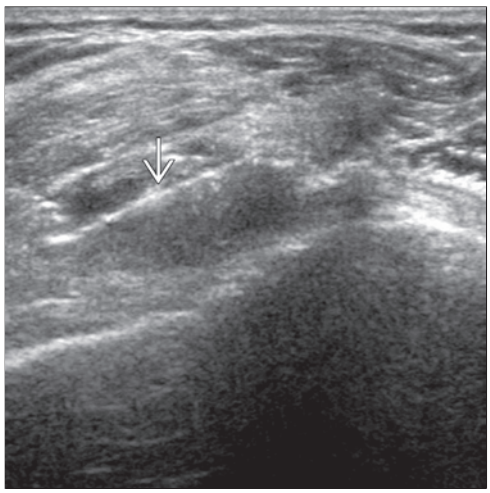


(Left) *Ultrasound-guided aspiration shows a patient with gouty arthritis and knee swelling. Aspirate from the suprapatellar pouch using a 20-g spinal needle* ➔ *revealed no bacterial growth. The patient was treated for gouty arthritis.* ***(Right)*** *Ultrasound-guided biopsy shows a suspected sarcoma in the popliteal fossa. A Tru-Cut biopsy needle* ➔ *was inserted via a coaxial needle* ➔ *medially to avoid the popliteal vessels* ➔. *Histology confirmed the mass to be a hematoma.*

Ultrasound-Guided Biopsy



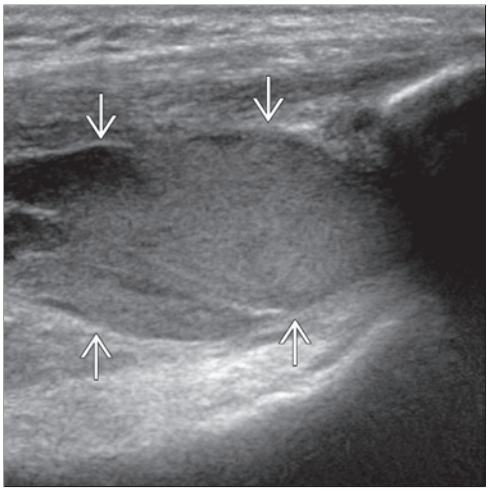
Ultrasound-Guided Biopsy



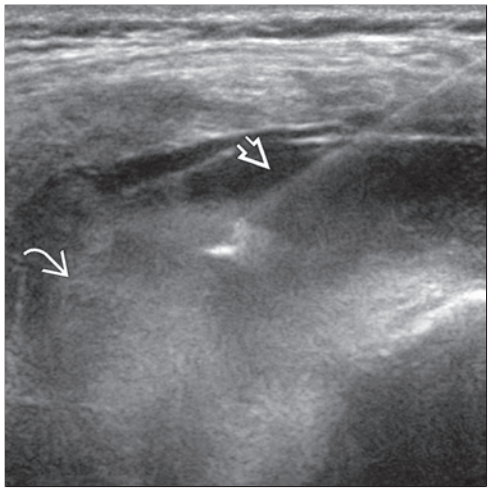
(Left) *Longitudinal ultrasound prior to biopsy shows an oval-shaped hypoechoic mass* ➔ *in the suprapatellar pouch superficial to the distal femur* ➔. ***(Right)*** *Longitudinal ultrasound of the same tumor during ultrasound-guided biopsy shows a 16-g biopsy needle* ➔ *that has been inserted through a 15-g coaxial needle. Histology confirmed localized pigmented villonodular synovitis (focal nodular synovitis).*

KNEE PROCEDURES

Radiosynovectomy

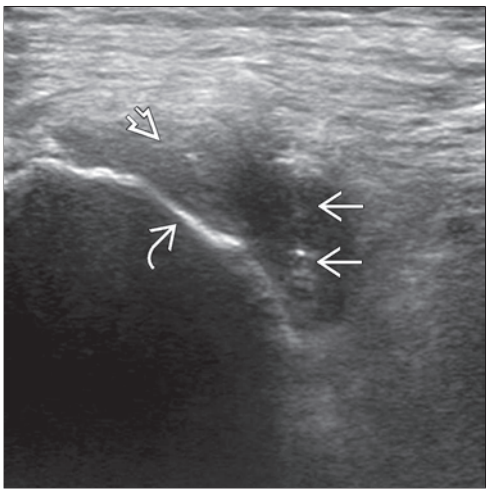


Radiosynovectomy

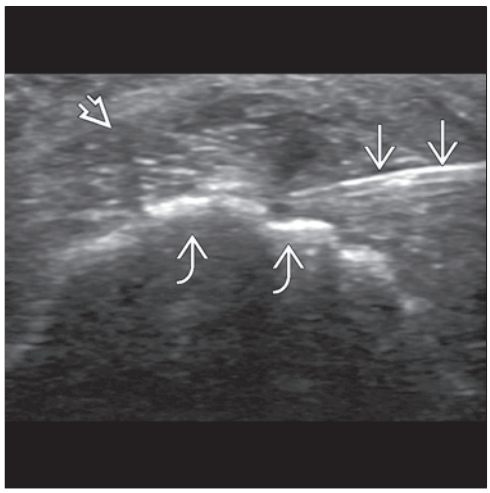


(Left) *Preliminary longitudinal ultrasound in a hemophiliac patient shows a hemarthrosis of the suprapatellar pouch* ➔ *with fine echogenicity of the suprapatellar pouch.* ***(Right)*** *Longitudinal ultrasound during aspiration shows a 20-g spinal needle* ➔ *inserted into the hemorrhagic knee effusion* ➔*. Radioactive Yttrium was then injected to reduce synovial proliferation. Ultrasound-guided injection prevents inadvertent extraarticular injection.*

Dry Needling

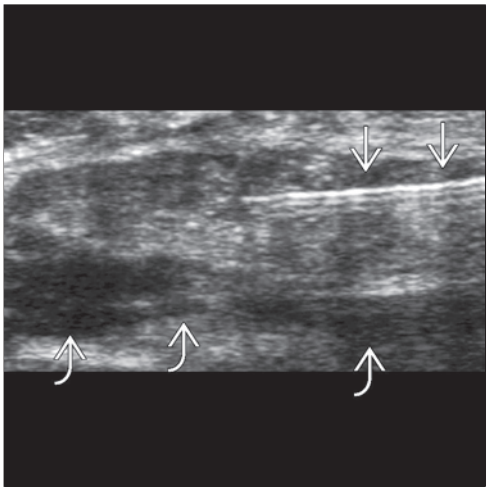


Dry Needling

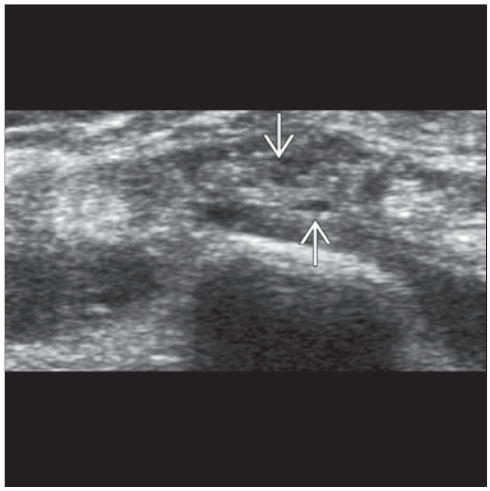


(Left) *Transverse ultrasound during dry needling treatment of semimembranous tendinosis shows a 23-g needle* ➔ *present within the hypoechoic semimembranous tendon* ➔ *close to the tibial insertion* ➔*. (Courtesy S. James, MD.)* ***(Right)*** *Transverse ultrasound shows dry needling treatment of the distal patellar tendon using a 21-g needle* ➔ *inserted into the tendon close to the tibial insertion* ➔*. The distal patellar tendon* ➔ *is moderately thickened and hypoechoic due to tendinosis. (Courtesy S. James, MD.)*

Dry Needling and ABI

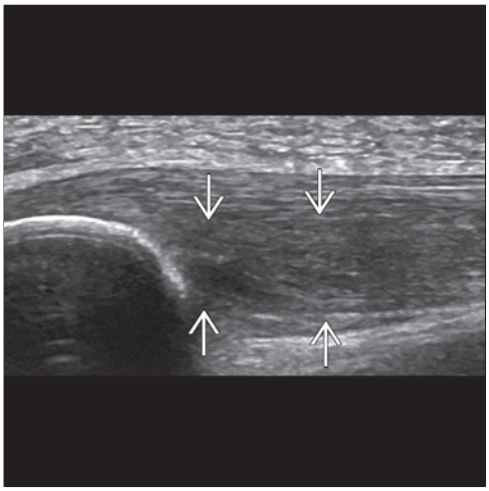


After Dry Needling and ABI

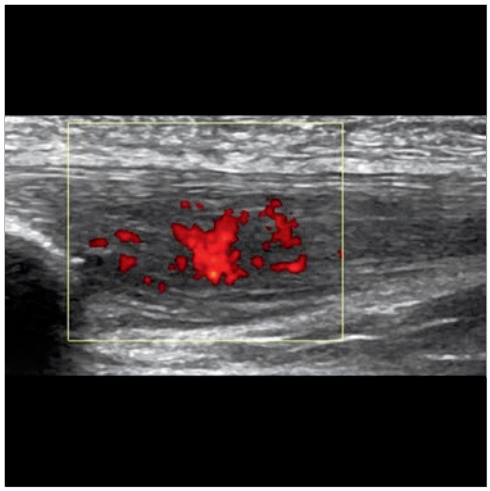


(Left) *Transverse ultrasound during dry needling shows patellar tendinosis using a 21-g needle* ➔*. The fluid present deep to the tendon* ➔ *is within the infrapatellar bursa, which has been distended with lignocaine. Dry needling was followed by autologous blood injection (ABI) (2-3 mL) using the same needle and approach.* ***(Right)*** *Transverse ultrasound of the same patellar tendon after dry needling and ABI shows at least 2 small hypoechoic fenestration clefts* ➔ *due to injected blood.*

Before Dry Needling and ABI

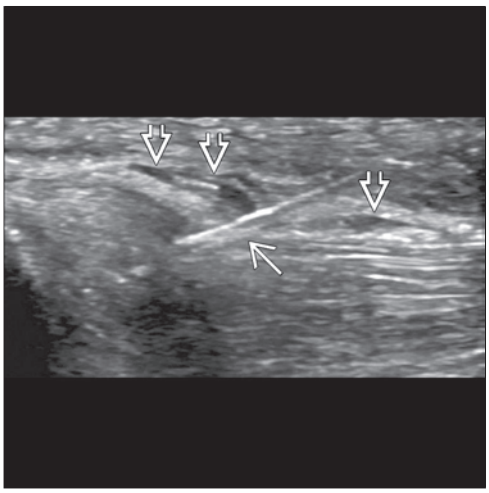


Before Dry Needling and ABI

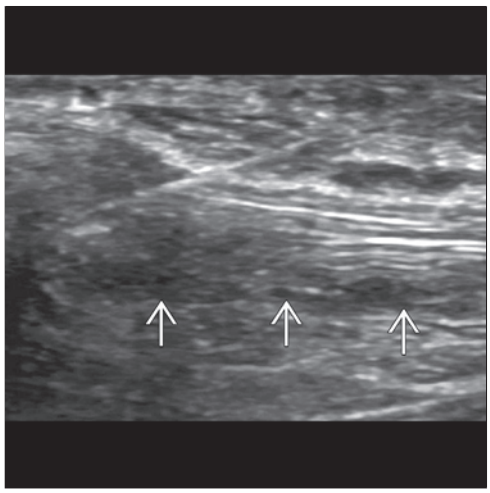


(Left) *Preliminary longitudinal ultrasound shows moderate to severe proximal patellar tendinosis, particularly affecting the deep fibers ➔ of the patellar tendon with marked tendon thickening, loss of fibrillar echotexture, and hypoechogenicity.* ***(Right)*** *Power Doppler ultrasound of the same area shows moderate to severe hyperemia of the more severe area of tendinosis, indicative of active disease.*

Dry Needling and ABI

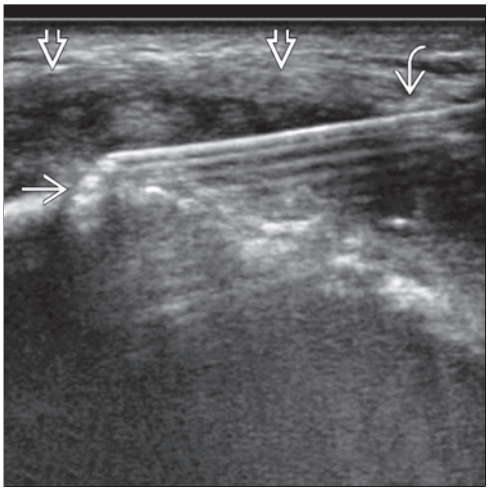


Dry Needling and ABI

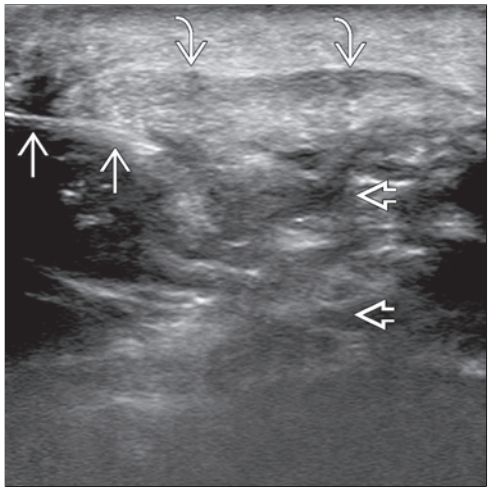


(Left) *Longitudinal ultrasound shows the same patient during dry needling using a 21-g needle ➔. Note the thin rim of anesthetic fluid (1% lignocaine) on the tendon surface ➔.* ***(Right)*** *After dry needling, 2-3 mL of autologous blood was injected into the center of the patellar tendon at the site of most severe tendinosis. Well-defined, linear fenestration clefts are present within the tendon due to this injected fluid ➔.*

PRP Injection



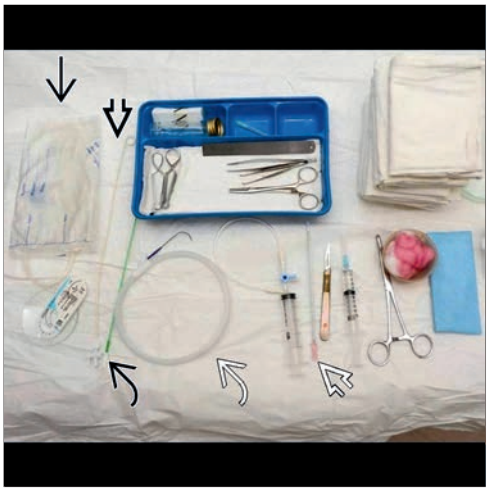
Peritendinous Steroid Injection



(Left) *Transverse ultrasound during injection (18-g intravenous needle ➔) of 6 mL platelet-rich plasma solution into the quadriceps tendon ➔ for treatment of tendinosis. Microbubbles are present at the needle tip ➔.* ***(Right)*** *Transverse ultrasound shows injection of 1 mL (40 mg/mL) methylprednisolone with 0.5 mL (1%) lignocaine deep to the patellar tendon ➔ using a 23-g spinal needle ➔ to treat Hoffa fat pad ➔ impingement syndrome. (Courtesy S. James, MD.)*

KNEE PROCEDURES

Drainage Set



Prepping Site



(Left) *Setup used for knee joint drainage procedure includes drainage bag, sutures, pigtail catheter, dilator, guidewire, syringe for aspiration, diamond needle, scalpel, syringe for local anesthetic, forceps, and cotton buds.* ***(Right)*** *Preparing the sterile field at the puncture site with chlorhexidine solution minimizes the risk of infection. Sterile drapes are then placed around the puncture site.*

Local Anesthetic



Stab Incision



(Left) *After determining a suitable puncture site on preliminary ultrasound, the puncture site is anesthetized with local anesthetic (3 mL 1% lignocaine) using a 23-g hypodermic needle. A sterile probe cover is wrapped around the transducer. Sterile ultrasound gel can be used during ultrasound scanning.* ***(Right)*** *A stab incision of the skin at the anesthetized puncture site is performed. A sharp, small, deep stab incision ensures adequate incision of the subdermal fascia with only a small cutaneous scar.*

Seldinger Technique

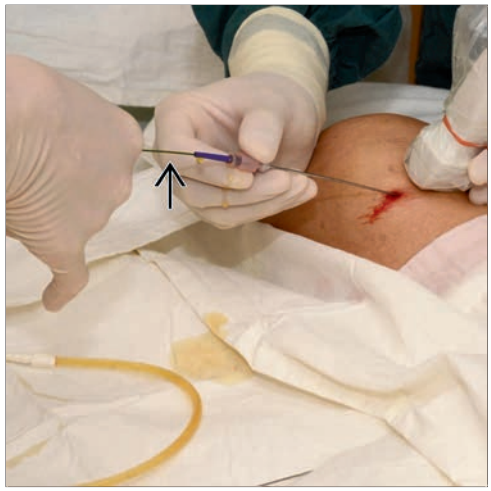


Needle Position Confirmed by Aspiration

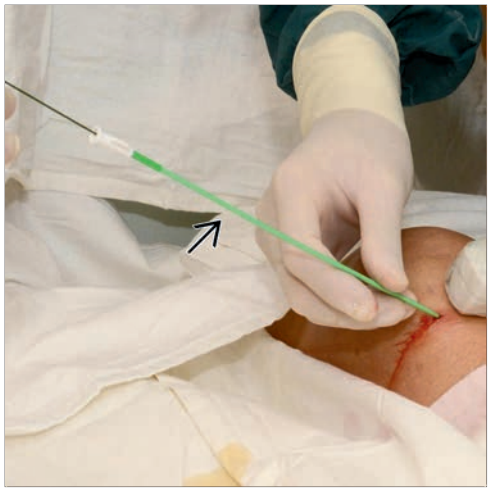


(Left) *Seldinger technique is used to drain the chronic knee effusion due to low-grade infection. An 18-g sheathed needle is used to puncture the knee capsule under ultrasound guidance.* ***(Right)*** *The needle position can be confirmed by free aspiration of fluid from the needle. The 1st fluid specimen aspirated is saved and sent for culture and cytology. Try not to aspirate all of the effusion, since this fluid facilitates subsequent guidewire and catheter insertion.*

Guidewire Insertion



Tract Dilatation

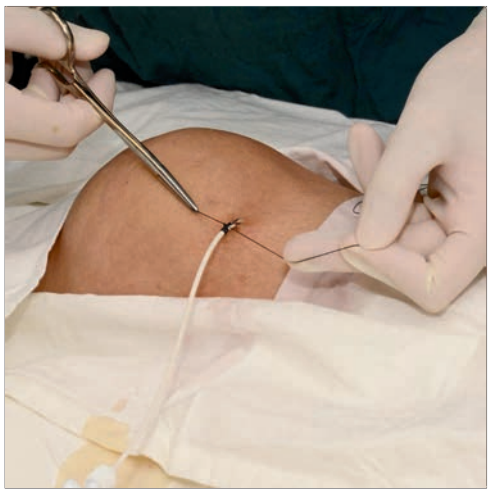


(Left) *After puncturing the knee capsule and confirming the needle tip position with ultrasound, a guidewire ⇨ is inserted through the needle into the knee joint. At this stage, the needle should be kept stable and straight to prevent kinking of the guidewire.* ***(Right)*** *The needle is then removed slowly, leaving the guidewire in situ. The tract is serially dilated with a 6 Fr followed by a 8 Fr dilator ⇨. The guidewire should be kept stable to prevent it from slipping out.*

Catheter Insertion



Catheter Fixation

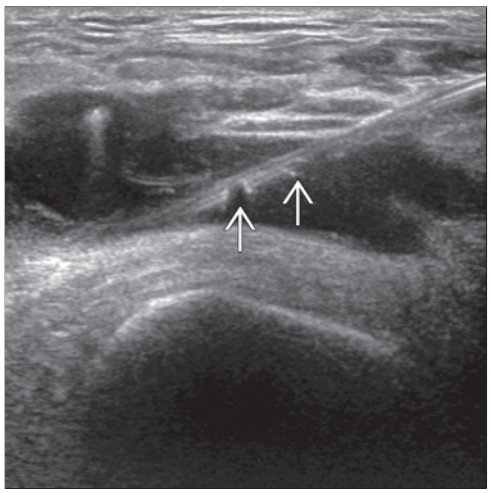


(Left) *After the tract is fully dilated, an 8 Fr side-hole catheter (pigtail catheter) ⇨ is inserted over the guidewire into the knee joint. Ultrasound is used to confirm catheter position within the knee joint. Larger catheters are used for collections with more complex, viscous fluid.* ***(Right)*** *The guidewire is then gently pulled out, and the catheter is secured by sutures to the skin. Gauze and plastic tape provide additional catheter protection.*

Confirmation by Aspiration



Confirmation by Ultrasound

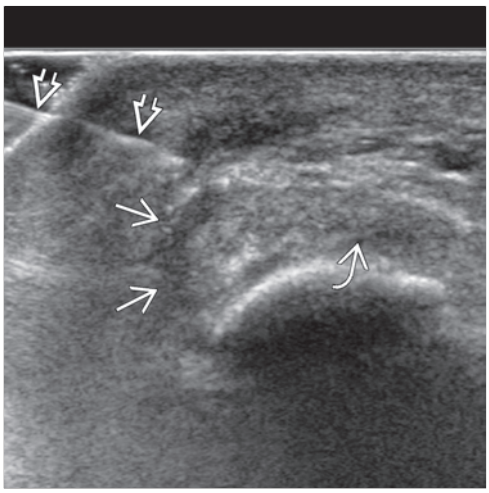


(Left) *A syringe is connected to the catheter through a 3-way stopcock and as much fluid is aspirated as possible. The 8 Fr catheter is then connected to a drainage bag for further gravity-assisted drainage.* ***(Right)*** *Transverse ultrasound after the procedure confirms the position of the catheter within the suprapatellar pouch of the knee joint. The catheter side holes ➔ through which knee joint fluid can freely drain are visible.*

ANKLE AND FOOT PROCEDURES



Clinical photo shows transverse approach for injection of plantar fasciitis. The patient lies prone on the examination table. The needle is inserted medially, almost horizontally.



Transverse ultrasound shows steroid injection for plantar fasciitis. A 23-g intravenous needle is inserted medially. Short-acting steroid (hydrocortisone 40 mg) is injected superficial to the plantar fascia.

PRE-PROCEDURE

Indications

- Aspiration or intraarticular injection
  - Suspected septic arthritis or crystal arthropathy
  - Therapeutic for control of inflammation or pain relief
  - Diagnostic to determine origin of pain preoperatively
  - MR, CT, or conventional arthrography
- Ganglion cyst aspiration: Pain relief
  - No pretest ultrasound predictor of content viscosity
- Peritendon therapy: Pain relief
  - Mainly to Achilles tendon, posterior tibialis, & peroneal tendons
- Plantar fasciitis injection: Pain relief
  - Helpful in cases resistant to standard treatment
- Morton neuroma injection: Pain relief
- Forefoot bursal injection: Pain relief
  - Submetatarsal or intermetatarsal bursitis

Getting Started

- Things to check
  - Check patient identity, type and side of procedure
  - Signed informed consent
    - Achilles tendon intervention: Risk of tendon rupture
    - Plantar fascia injection: Risk of fascial rupture and heel pad atrophy
    - Superficial steroid injection: Skin depigmentation change, particularly in patients who have had multiple injections and those with darker skin
  - Discuss risk of infection, allergy, and bleeding
  - Sedation rarely required
- Medications
  - Local anesthetic (LA) for skin (2 mL 1% lignocaine)
  - Local anesthetic for intraarticular injection
    - 2-5 mL 1-2% lignocaine or 3-5 mL 0.25-0.5% bupivacaine (Marcaine)
  - Steroid
    - Short acting (hydrocortisone), medium acting (methylprednisolone), and long acting (dexamethasone)
    - Equivalent dosage
      - Hydrocortisone 20 mg = methylprednisolone 5 mg = dexamethasone 0.75 mg
  - Hyaluronic acid
    - Replaces synovial fluid
    - Good response, better than steroid, especially in early osteoarthritis
    - Relatively expensive
  - Contrast
    - CT arthrography: Iodinated contrast, e.g., iohexol (Omnipaque) 300 ± 0.1 mL of 1:1000 epinephrine
    - MR arthrography: Dilute gadolinium (1:1000), e.g., 0.1 mL gadolinium in 10 mL normal saline solution
- Equipment list
  - Sterile set
  - Spinal or intravenous needle 18- to 25-g
  - Thin extension tubing (250 mm long, 8.5 Fr, 0.4 mL dead space)
  - Syringes for LA, aspiration, & injection
  - Sterile bottle & specimen bottle

PROCEDURE

Joint Aspiration or Injection

- Sterile technique, skin & underlying soft tissues anesthetized at puncture site
- General clues irrespective of joint injected
  - Use smallest needle sufficient to reach joint (22- to 27-g)
    - Large needle if aspirating purulent fluid
  - Use free-hand technique to advance needle into joint space under real-time imaging
    - Avoid puncture of neurovascular bundle by carefully planning approach
  - Can use long-axis (preferable) or short-axis approach
  - Ensure real time that needle tip is within joint space & directed toward any joint fluid
    - If moderate to large effusion present, aspirate joint fluid prior to injection
  - Avoid injection of bubbles by flushing syringe & tubing

Key Facts

Pre-Procedure

- **Indication**
- Aspiration or injection of joint fluid
- Intraarticular injection of medication or contrast
- Paraarticular aspiration or injection
  - Cyst aspiration, peritendon injection, plantar fasciitis injection, Morton neuroma injection, forefoot bursitis injection

Procedure

- Joint aspiration or injection
  - Diagnostic to determine site of pain or therapeutic to relieve pain
- Ganglion cyst aspiration
  - ≥ 19-g needle for more viscous contents
- Peritendon injection: Approach depends on site of tendon disease
  - Steroid injection, platelet-rich plasma (PRP)
- For Achilles tendinosis, various treatments & approaches are possible
  - Reduce neovascularity: Sclerotherapy, electrocoagulation or brisement
  - Stimulate healing response: Dry needling, autologous blood or PRP, or prolotherapy
  - Reduce inflammation: Steroid
- Plantar fasciitis: Medial approach preferable
  - Dry needling, steroid (short acting, preferably)
- Morton neuroma
  - Steroid ± alcohol ablation (if not responsive)
- Forefoot bursitis: Plantar approach
  - Steroid injection

  - Free flow of fluid helps confirm intraarticular position of needle tip
  - Rotate or realign bevel of needle if not flowing freely
  - For diagnostic test to determine origin of pain
    - Assess pain level prior to anesthetic injection (visual analogue score [VAS])
    - Reassess VAS post injection, prior to anesthetic injection of subsequent joint
- Tibiotalar joint injection
  - Anterior approach: Patient supine, probe in sagittal plane
    - Avoid anterior tibial neurovascular bundle located just medial to midline
    - Deep peroneal nerve crosses over to lateral side of anterior tibial artery at ankle joint
- Subtalar joint injection
  - Lateral approach: Anterior or posterior, needle passing deep to fibula
  - Posterior approach: Patient in prone position
    - Sweep off Achilles tendon
    - Visualize posterior recess of subtalar joint
    - Posteromedial approach preferred to avoid sural nerve, which runs deep to retromalleolar peroneal tendons

Ganglion Cyst Aspiration

- 21-g needle advanced into ganglion
  - ≥ 19-g needed for more viscous content
- Injecting a little lignocaine into ganglion can loosen cyst content if nothing can be aspirated initially or if fluid is quite viscous
- ± hyaluronidase injection pre treatment
- ± steroid injection post aspiration
- ± fenestration of cyst walls with needle several times during procedure
  - Potentially allows cyst fluid to escape and reduces chance of recurrence

Achilles Tendinosis Treatment

- Patient in prone position with ankle & foot hanging over edge of bed
  - Medial axial approach to avoid sural nerve, which runs just superficial and lateral to Achilles tendon
  - Longitudinal approach
- Reduce tendon & paratenon neovascularity
  - Sclerotherapy: Polidocanol (2-4 mL at 5 mg/mL) into peritendinous (not tendon) vessels
    - Good short-term results
    - Multiple treatments often necessary
  - Electrocoagulation (at 20-25 W): Needle placed against vessels (arteries or veins) entering tendon
    - Effect may be short term
  - Brisement: High-volume injection of normal saline (20-40 mL), local anesthetic solution (10 mL of 0.5% bupivacaine), and steroid (25 mg of hydrocortisone) between Achilles tendon & paratenon
    - Aim is to strip paratenon & clear adhesions
    - Local mechanical effect causes neovessels to break or occlude
    - Neural ingrowth accompanying neovessels is also potentially damaged
    - Reduces pain & improves function both short & long term
- Stimulate healing response
  - Dry needling: Repeated fenestration of area of localized tendinosis
    - Often followed by autologous blood injection (ABI) or platelet-rich plasma (PRP) injection
  - ABI or PRP injection: ~ 3 mL injected into area of tendinosis
    - No study performed on treatment benefit for dry needling or PRP
  - Prolotherapy (or regenerative injection therapy): 20-40 mL of irritant such as hyperosmolar dextrose injected around tendon insertion
    - Pilot study shows significant reduction in tendon pain at rest & during tendon-loading activities
    - Practical tips for ABI, PRP, or high-volume stripping
      - Use Luer lock syringes for ABI/PRP/saline injection into tendon to guard against explosive leakage from excessive back pressure
      - Inject blood/PRP/saline using gentle pressure push/release technique to avoid excessive back pressure
- Reduce inflammation
  - Peritendinous injection of 20-40 mg of methylprednisolone or triamcinolone mixed with lignocaine ± bupivacaine

- 21- or 23-g needle is used for injection
  - High frequency of relapse

Treatment of Other Tendons

- Approach tailored according to particular tendon segment injected

Plantar Fasciitis Injection

- Patient in prone position with ankle & foot hanging over edge of bed
  - Medial axial approach allows local anesthetic to be injected into skin to reduce overall pain of procedure
    - Medial side selected as plantar fasciitis usually affects central band of plantar fascia insertion into medial calcaneal tuberosity
  - Plantar longitudinal approach more painful (thick plantar skin)
- 23-g needle is used for injection
- ± dry needling of plantar fascia initially
- Steroid & local anesthetic mixture then injected deep or superficial to fascia but not into fascia
  - Not possible to inject into fascia
  - Reposition needle during injection to disperse injectate over fascial surface, particularly over medial aspect of fascia close to attachment
- Short-acting (such as hydrocortisone) rather than long-acting steroid preferred in total dose of ~ 40 mg to reduce risk of heel fat pad atrophy

Morton Neuroma Injection

- Main bulk of neuroma mass lies plantar to metatarsal heads
- Dorsal (webspace) or plantar approaches
  - Dorsal approach preferable
    - Patient supine on couch
    - Aim to puncture between toes above skin fold in longitudinal plane
    - Transducer is positioned either dorsal or plantar to webspace, depending on which is easier, and aligned parallel to needle (longitudinal)
    - Needle inserted into webspace almost parallel to transducer
  - Plantar approach
    - Transverse or longitudinal, more painful than dorsal webspace approach
- 23-g needle is used for injection
- Steroid injection, typically 40 mg of methylprednisolone along with bupivacaine
- Provides several months of pain relief
- After 3 months, if good symptomatic relief from 1st injection, a 2nd steroid injection can be given
- If neuroma is large (> 5 mm wide) or does not respond to steroid injection, neuroablative therapy with alcohol injection will help to relieve symptoms

Forefoot Bursal Injection

- Usually plantar approach, or rarely dorsal or intermetatarsal approach
- 23-g needle is used for aspiration or injection

Findings and Reporting

- Consider reporting on these aspects
  - Initial ultrasound findings
    - Do not do any interventional procedure without 1st making full assessment of ultrasound findings & reporting clearly on these findings
    - Provide objective (quantitative or semiquantitative) criteria of baseline disease severity, e.g., thickness of plantar fascia (mm) or degree of tendon/peritendinous vascularity (absent, minimal, mild, moderate, severe)
  - Report on type and amount of local anesthetic used
  - Type & size of needle used
  - Volume, color, & viscosity of joint fluid aspirated
  - Volume & type of fluid injected
  - If only friable material obtained at biopsy
  - Unexpected adverse occurrence during procedure, e.g., arterial puncture
    - Report even though no immediate complications as there is potential for late complication
  - Immediate complication (e.g., excessive bleeding)

POST-PROCEDURE

Immediate Aftercare

- MR or CT arthrography within 30 min of arthrography as contrast will absorb
- Joint aspirate should be sent, where appropriate, for
  - Cell count, Gram stain, microscopy & culture (aerobic & anaerobic), & sensitivity
  - Cytology, crystal analysis (fresh specimen for crystals as they are dissolved by water, alcohol, formalin)

OUTCOMES

Problems

- Discomfort for 1-2 days after intraarticular injection of contrast or steroid, as this can induce a chemical synovitis

Complications

- Most feared complication(s)
  - Infection, e.g., septic arthritis
    - Do not inject joint if overlying tissue infected
    - Provide antibiotic cover if lymphoedema
  - Steroid-induced fat pad atrophy, skin atrophy, or depigmentation
  - Tendon rupture following PRP or ABI
- Immediate/periprocedural complication(s)
  - Bleeding, especially for those with bleeding diathesis
  - Extravasation of contrast or medication
    - Rest joint for 20 minutes following injection
  - Capsular rupture
  - Allergy to injectate
  - Injury to neurovascular bundle
- Delayed complication(s)
  - Delayed allergic reaction (uncommon)
  - Tendon or fascia rupture

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Achilles Tendon Injection

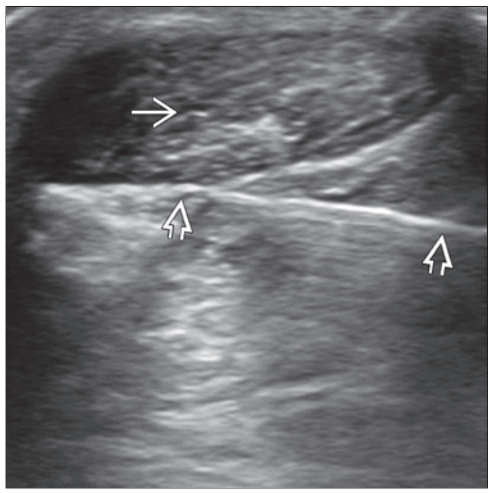


Achilles Tendon Injection

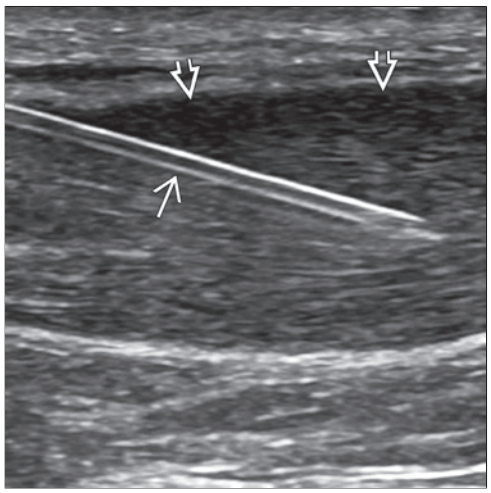


(Left) *Clinical photo shows longitudinal approach for injection of the Achilles tendon. Patient lies prone on the examination table.* ***(Right)*** *Clinical photo shows transverse approach for injection of the Achilles tendon. The needle is inserted medially to avoid the sural nerve, which runs superficial and lateral to the Achilles tendon.*

Achilles Tendon Injection

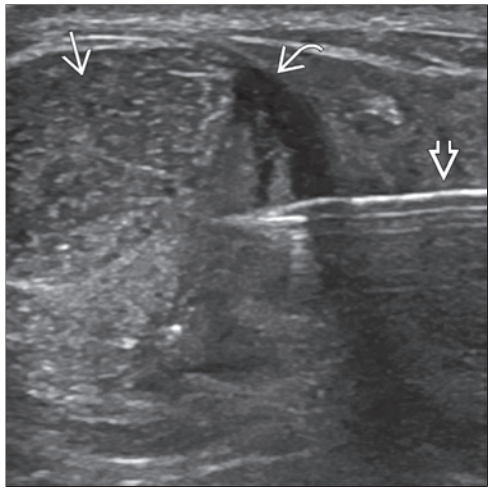


Achilles Tendon Dry Needling

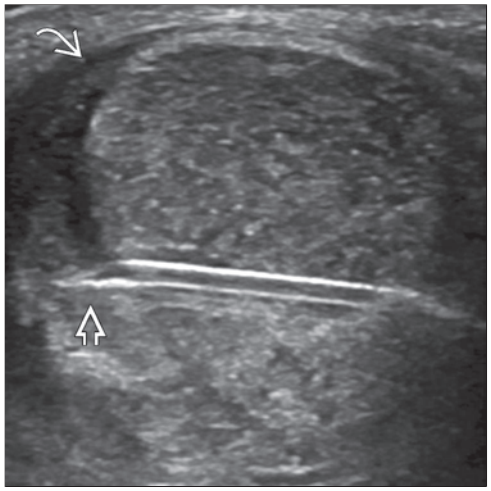


(Left) *Transverse ultrasound shows stripping of the Achilles paratenon by high-volume (20-40 mL) injection of normal saline using a 23-g intravenous needle. (Courtesy S. James, MD.)* ***(Right)*** *Longitudinal ultrasound shows dry needling of Achilles tendinosis using a 21-g needle. The hypoechoic rim superficially is from 1% lignocaine instilled deep to the paratenon prior to dry needling to reduce discomfort during the procedure.*

Achilles Tendon High-Volume Injection (Brisement)



Achilles Tendon High-Volume Injection (Brisement)

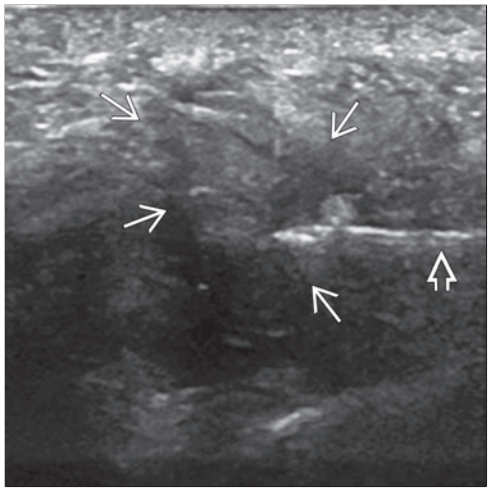


(Left) *Transverse ultrasound shows stripping of the Achilles paratenon by high-volume injection of a mixture of 10 mL 0.5% bupivacaine and 40 mL normal saline using a 21-g intravenous needle.* ***(Right)*** *Transverse ultrasound of the same patient shows advancement of the needle around the tendon to ensure thorough stripping of the paratenon. The bevel has been turned to face upward to ensure the injection is deep to the paratenon.*

Morton Neuroma Injection



Morton Neuroma Injection

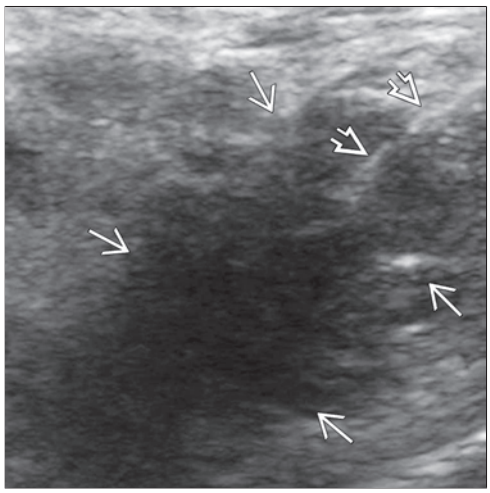


(Left) *Clinical photo shows dorsal webspace approach for injection of Morton neuroma. Patient lies supine on the examination table. The needle is placed between toes puncturing above the skin fold in a longitudinal plane. The transducer is placed parallel to the needle (longitudinal) either dorsal or plantar to the webspace, depending of which is easier.* ***(Right)*** *Longitudinal ultrasound shows steroid injection of Morton neuroma ➔ via digital webspace dorsally. A 23-g needle ➔ is inserted almost parallel to the probe.*

Morton Neuroma Injection



Morton Neuroma Injection

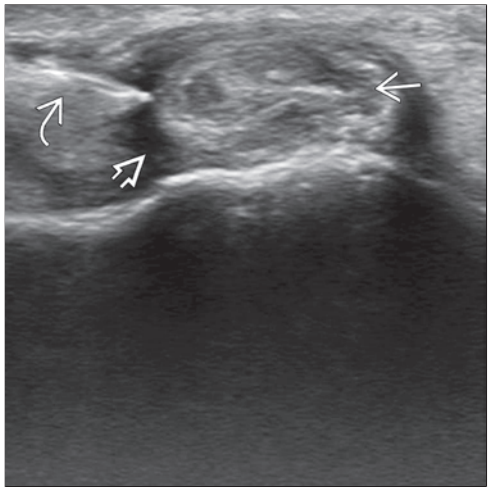


(Left) *Clinical photo shows plantar longitudinal approach for injection of Morton neuroma. Patient lies prone on the examination table.* ***(Right)*** *Longitudinal ultrasound shows a large Morton neuroma ➔. Steroid (methylprednisolone 40 mg) and local anesthetic (5 mL 0.5% bupivacaine) injection was performed longitudinally on plantar side via a 23-g needle ➔. (Courtesy S. James, MD.)*

Peroneal Tendon Injection



Peroneal Tendon Injection

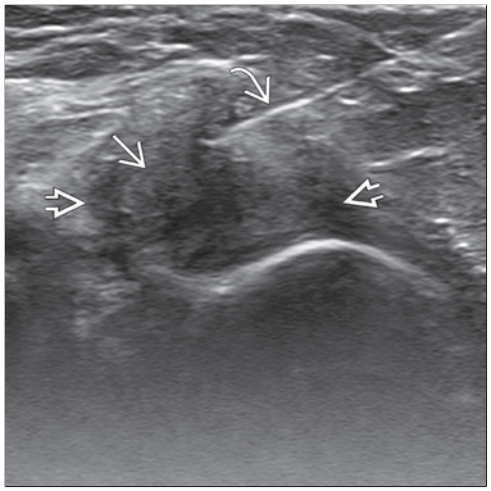


(Left) *Clinical photo shows transverse approach for injection around retromalleolar peroneal tendons.* ***(Right)*** *Transverse ultrasound shows steroid injection (methylprednisolone 40 mg) to the common tendon sheath of the retromalleolar peroneal tendons ➔ via a 23-g intravenous needle ➔. The steroid injectate ➔ will disperse proximally and distally along the tendon sheath. (Courtesy S. James, MD.)*

Posterior Tibialis Tendon Injection



Posterior Tibialis Tendon Injection

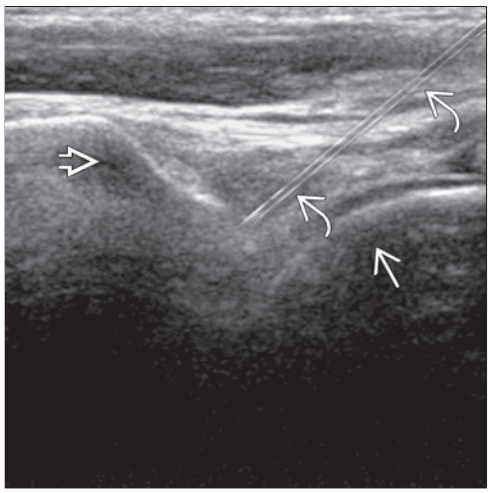


(Left) *Clinical photo shows transverse approach for injection of the posterior tibialis tendon.* ***(Right)*** *Transverse ultrasound shows steroid (methylprednisolone 40 mg) injection to the tendon sheath of the posterior tibialis tendon ➔ via a 23-g intravenous needle ➔. The needle tip can be inserted into the tendon and then slowly withdrawn until there is free flow and dispersion of the injectate along the tendon sheath ➔. (Courtesy S. James, MD.)*

Ankle Joint Injection or Aspiration



Ankle Joint Injection or Aspiration

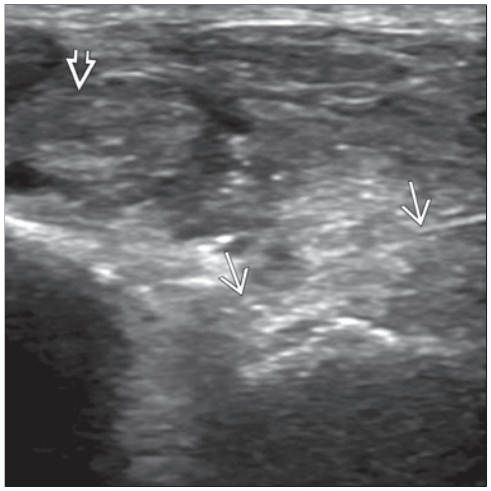


(Left) *Clinical photo shows longitudinal anterior approach for tibiotalar joint injection or aspiration. Care must be taken to avoid the neurovascular bundle and particularly the deep peroneal nerve, which lies just lateral to the anterior tibial artery at the ankle.* ***(Right)*** *Longitudinal ultrasound shows simulated ultrasound-guided injection of tibiotalar articulation. The simulated needle ➔ is inserted between the distal tibia ➔ and talus ➔.*

Subtalar Joint Injection



Subtalar Joint Injection



(Left) *Clinical photo shows longitudinal lateral approach for subtalar joint injection or aspiration. Care must be taken to avoid the peroneal tendons and sural nerve, which lie adjacent to the subtalar articulation laterally. The sural nerve lies deep to the peroneal tendons.* ***(Right)*** *Longitudinal ultrasound shows subtalar joint injection. A 23-g needle ➔ is present at the anterior edge of the subtalar joint. The peroneal tendons ➔ are seen lying to the left side.*